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THE GEOLOGY AND GEOMORPHOLOGY OF THE TEXAS CAVES, SOUTHEASTERN QUEENSLAND

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ABSTRACT

The Texas Caves are in the only significant karst area in southeast Queensland. The caves occur in Carboniferous limestone lenses within the Texas Beds of the New England Fold Belt. Pleistocene stream incision exposed the limestones and allowed cave development to begin in late Pleistocene times.

The partly collapsed Glenlyon Cave System is a subterranean cutoff of a meander spur of Pike Creek. High energy stream passages are superimposed on an earlier low energy phreatic system. Complete capture of the creek has not occurred as collapsed sections of the cave have restricted water flow through the system. On Viator Hill there are two moderately large caves and a number of smaller 'potholes'. These are dominantly low energy phreatic systems. Once formed, the two larger caves show a history of initial sedimentation and speleothem formation, followed by erosion and then further sedimentation and speleothem growth. The depositional periods are thought to relate to deteriorating climates and aggradation of the surface stream channel, while the intervening erosional period relates to a stable climate and stream incision. The Viator Hill cave sediments are mainly silty clays with locally abundant clay aggregates derived from surface soils. Some old guano deposits are incorporated. The sediments of the Glenlyon System are stream deposited silts and fine sand, with minor gravel.

Surface karst forms include a diversity of well-developed karren forms, as well as dolines, karst windows, and a natural arch resulting from collapse in the Glenlyon System.

The Texas Caves is a general term for the group of caves found adjacent to Pike Creek, a few kilometres upstream from the Glenlyon damsite and about 30 km east of the town of Texas, in the Border Rivers District of southeast Queensland. With the exception of one cave at Riverton, 10 km to the south, the Texas Caves are the only known limestone caves in southeast Queensland. The caves have been flooded by the Glenlyon Dam. This report will record the features of the caves area together with an interpretation of their development.

Main Viator Cave and the caves and dolines of the Glenlyon System have been known for a considerable time (Robinson 1978). In Main Viator Cave signatures have been seen dating back as far as 1892. The area has been visited regularly by the University of Queensland Speleological Society (UQSS) since its inception early in the 1960's and the society was the main body behind the unsuccessful campaign to prevent the flooding of the caves (UQSS 1973). The society discovered and explored Russenden Cave as well as most of the smaller caves on Viator Hill, and has explored the Glenlyon System in detail. Most of the caves in the area are covered by published and unpublished maps prepared by the UQSS (see Appendix 1) and these provided the basis for the author's field work. The maps accompanying this report are generally based on the UQSS surveys with some additional details added by the author. Although brief descriptions and information on aspects of the caves have been given from time to time in the UQSS newsletter *Down Under,* and brief summaries of the caves appear in the Australian Speleo Handbook (Matthews 1968, and in prep.), few detailed descriptions have been published (e.g. Shannon 1975, Grimes 1975, Grimes and Brown 1976). Interim reports on the studies carried out by the Geological Survey of Queensland (GSQ) are on file at that office (Tweedale 1970, Grimes 1973).

Field work involved general mapping and observations on the geology and geomorphology of the area. A brief preliminary survey was made in 1970 by G. Twidale, A. Graham, and E. Howe (Twidale 1970). The author worked in the area between 1973 and 1975 and in addition visited the area a number of times with UQSS parties. Most, but not all, of the caves were entered and information on the remainder was provided by UQSS members. Several levelling traverses were made on the surface to allow comparison of the cave levels with the stream terraces, and to provide information for the contour map of the Glenlyon System. The traverses were tied into previous surveys by the UQSS and to Water Conservation and Irrigation Commission (WCIC) survey marks which provided absolute elvations. Fossils were collected from the limestones at a number of localities and some of these are described by P. J. G. Fleming in Appendix 2. Several auger holes were drilled in Main Viator and Russenden Caves in order to study the cave sediments. Archer (1978) examined the bone deposits.

Laboratory tests on the cave sediments included mechanical analysis, spot tests for carbonate and phosphate, pH testing (using the CSIRO soil testing kit) and X-ray analysis of clay minerals. Detailed results are listed in Grimes (1977) and summarised in this report Attempts to extract pollen and spores from the sediments proved unsuccessful (H. Hekel and C. Bell, pers. comms.). Sediment colours are based on the revised Standard Soil Colour Charts of Oyama and Takehara (1967). Thin sections were cut from a number of limestone samples.

A grid has been used on the surface maps and the maps of the larger caves to facilitate references to localities. This grid is oriented to magnetic north (1975) and based on the WCIC bench mark 78 A which has been given the arbitrary co-ordinates of 2 000 m east and 3 000 m north. Grid references to the small scale Map 10 are to the nearest ten metres and use the first three significant figures while references to the larger scale Map 9 and the cave maps are to the nearest metre and use the last three significant figures.

The cave surveys are not all to the same standard and the accuracy has been indicated by use of the Cave Research Group of Great Britain (CRG) grading system which uses instruments and surveying techniques as a guide to accuracy (Sexton *in* Matthews 1968).

The terminology of cave features used here is basically that of Monroe (1970) and Jennings (1971). Some modifications and additional terms have been used and are briefly discussed here.

In Australia the term 'shawl' has often been applied in a general sense for all types of flowstone sheets hanging from roofs and projecting from walls. Here the term *curtain* is used for an undulating sheet, while *shawl* is restricted to Monroe's usage for a triangular sheet hanging from a ceiling. The term *ribbon* (Halliday 1974) is used here for a narrow, unconvolated sheet on a wall or sloping roof (Plate 3d).

The descriptive term *wall solution undercuts* is used for features illustrated in Plate 5a, that are attributed to prior water levels. They have no floor. Where more or less horizontal channels have been cut into a wall, and therefore have a narrow floor, the term *stream channel incut* is used and these are taken to indicate an old stream level at a time when the floor of the cave was higher.

Etch grooves are narrow, but relatively deep grooves often forming a network. They probably derive from solutional etching by water percolating through small joints in the rock. They are illustrated in Plate 4c and discussed in the section on the Dustbath (GL-6).

The term *blind shaft* is used here in preference to 'aven' in its English usage. When the hight is not more than twice the width, and it has a curved, bell-shaped form the term *bell-hole* is used (Plate 6a).

The two water filled shafts at the upstream end of the Glenlyon system have been called 'cenotes'. This is not a strictly correct usage of the term, which normally applies to much larger features, but it is retained here for conveniences of identification.

Red earth breccia is a term used here for consolidated cave deposits composed of limestone fragments and often bone material in a matrix of red earth; the whole commonly being cemented by calcite. The matrix is often more abundant than the limestone or bone fragments and there is a variation which consists of red earth fragments in a brown calcite 'tufa' cement.

REGIONAL GEOLOGY

The regional geology of the area is shown in the inset to Map 10. The geology has been discussed by Lucas (1960), Olgers and Flood (1970), Olgers *et al.* (1974) and Senior (1973). A structural interpretation has been presented by Butler (1974). The Cainozoic history can be compared with that presented by Browne (1969) for northern New South Wales. The limestone resources of the area have been delineated by Siemon (1973). The following discussion is based largely on these reports.

The caves occur in limestone lenses within the Texas Beds. These beds probably range in age from Devonian to Late Carboniferous, though the limestones containing the caves have Early Carboniferous (Visean) corals (Olgers *et al.* 1974;

and Appendix 2). The Texas Beds form part of the Wooloomin-Texas Block of the New England Fold Belt. They are a thick sequence of regularly bedded lithic sandstone and mudstone with minor chert, jasper, intraformational conglomerate, intermediate volcanics, and limestone lenses. Olgers *et al.* (1974) suggest that the sediments were probably all laid down in shallow water, but below wave base, and that thin submarine andesitic volcanics, up to 60 m thick, provided shallow 'banks' on which the coral reefs could be built. On the other hand Butler (1974) interprets the sediments as deep flysch deposits, and considers that the limestones are allochthonous blocks derived from the shelf to the south-west.

The Texas Beds were intensely deformed during a Carboniferous orogeny; dips are often steep to vertical and the beds are overturned in places. Butler (1974) interprets the structures as being due to a series of north-easterly moving nappes.

Permian sediments occur in fault blocks within the Texas Beds. Permian volcanics are found further east. The Beds have been intruded by Permian and Triassic granitic rocks of the New England Batholith.

The Jurassic and younger sediments of the Surat Basin overlie the Texas Beds to the north-west.

No detailed studies of the Cainozoic history of the region have been made and it is necessary to rely on general accounts in order to date the local features.

Basalt was extruded in parts of the region in late Oligocene and early Miocene times (Webb *et al.* 1967; Wellman and McDougall 1974). Senior (1973) indicates that these cover an early Tertiary lateritic surface.

A planation surface can be recognised in the area from summit conformities and occasional small plateau remnants at elevations at or above 600 m. This would appear to be the 'upper erosion surface' of Watkins (1967), which postdates early Miocene basalts. It may also correlate with the Miocene duricrusted peneplain postulated by Browne (1969) in northern NSW. Dissection of this surface would have been initiated by later uplift, the age of which is uncertain, though Browne (1969) suggests two phases: the late Miocene Macleay Epoch, and the late Pliocene and early Pleistocene Kosucisko Epoch.

The present stream valleys are the culmination of this erosion and the terraces and flood plains which occur in them are probably of late Pleistocene or Holocene age.

GEOLOGY OF THE CAVES AREA
(Map 10)

THE TEXAS BEDS: The Texas Beds in the caves area are composed mainly of dark grey to black massive mudstones which are strongly jointed. A few chert beds occur and also some outcrops of rhythmically interbedded mudstones and labile sandstones; dip measurements are only possible in these outcrops. The strike of the steeply inclined beds is to the northwest. Facing is not known. A tightly folded synform occurs at 258367 (Map 10) with nearly vertical dips on either side.

Most of the limestone is contained in large lenses up to 400 m wide and 1000 m long, though there are smaller lenses grading down to beds only a few metres across. The three main lenses, which contain the caves, are those of the Glenlyon System, Viator Hill, and the Whale Rock area (Map 10). The first two are probably continuous beneath the alluvium of Pike Creek. The Whale Rock lens may have been offset by faulting, though there is no field evidence for this. The limestones are dominantly medium to dark grey, fine-grained, partly recrystallised biomicrites, with crinoid plates, corals, calcareous algae, bryozoa, pelecypod and gastropod fragments, and foraminifera as the main fossil components. Oolites and pellets are locally abundant. In some places there are irregular bodies of limestone breccias, which have a matrix of calcite, chert, or dark lutite. These may be depositional breccias. Nodular chert replacements occur in several places and there has also been some local ferruginisation.

The limestones are generally massive and bedding can only be seen in a few localities (e.g. at 216335, where there are thin interbeds of mudstone). Calcite veins are very common and generally form an irregular network, though occasionally a dominant orientation can be discerned. Joints are common with dominant strikes to the northeast and the northwest (parallel to the regional strike). Joint roses are presented in Fig. 1. Most joints are nearly vertical, though locally there are some well developed subhorizontal and inclined sets.

A description of the coral species is given in Appendix 2; they indicate an early Carboniferous (Visean) age. In addition to the GSQ collection, fossils from the area are held at the University of Queensland, the Queensland Museum, and the Kedron Park Teachers College. A rather dispersed conodont fauna has also been extracted and is held at the University of Queensland, but has not been studied in detail (G. L. Forster, pers. comm.).

FIGURE 1

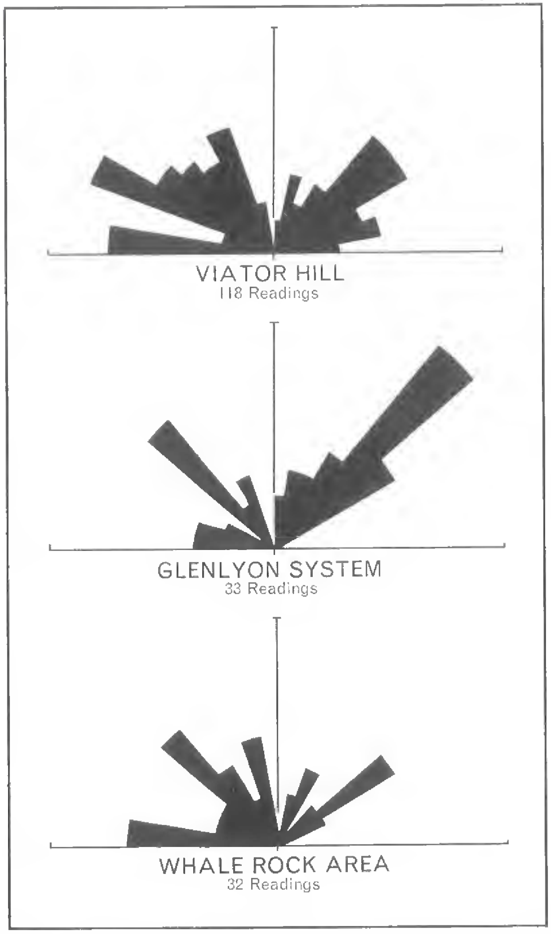

FIG. 1: Joint roses of Viator Hill, Glenlyon System and Whale Rock area.

THE CAINOZOIC SEQUENCE: A summit concordance at about 650 m in the hills above the valley may be related to the Miocene surface of Watkins (1967) and Browne (1969). The present deep valley of Pike Creek is the result of later erosion which is continuing at present. The caves, which lie in the lower part of this valley, were probably initiated in late Pleistocene times.

Alluvial terraces and high level gravels indicate several alternating stages of aggradation and incision of Pike Creek in the final stages of valley formation. These stages are contemporaneous with the evolution of the caves (see section on Cave development, and Table 1). Unfortunately no detailed studies of the terraces and their chronology has yet been attempted in the Border Rivers region.

The oldest alluvial deposits are scattered cobbles and pebbles which lie 10–15 m above the present stream bed. These are shown as Qpa on Map 10. The main alluvial terrace (Qa_2) is composed of clayey silt and fine sand and lies between six and eight metres above the present stream bed. Auger hole TA-1 (220315, Map 10) penetrated 4.4 m into this unit and revealed a soil of the Red-brown Earth type (in the usage of Stephens 1962). A detailed log is given in Grimes (1977). Below the Qa_2 terrace there is a less well-defined and less extensive level of Qa_1 deposits: clay, silt, sand, and travel with minimal soil development. This lies from two to six metres above the stream bed. The Qa_2 and Qa_1 terraces can both be seen in Plate 11a of this volume. The present stream bed (Qha) is made up of loose cobbles and pebbles, derived from Texas Beds lithologies, and minor sand and silt. Some higher banks of Qha cobbles are transitional with the lower part of the Qa_1 terrace. The depth of the alluvial deposits is not known, though at the damsite, downstream from the caves, drilling has indicated bedrock within a few metres of the present floor of the creek (WCIC 1973).

In addition to the terrace deposits there are colluvial deposits on the lower valley slopes which are sufficiently deep to mask the underlying geology. These have been mapped as Qc. An undifferentiated alluvial unit, Qa, has been mapped in some side valleys where the terrace levels cannot be distinguished.

The sequence of terraces could be due to eustatic changes of sea level, intermittent tectonic uplift, climatic variations, or a combination of these. Eustatic effects would probably not be great in view of the long distance between these inland draining streams and the oceanic base level at the mouth of the Murray River. Tectonic effects are possible; valley-in-valley forms are recorded in the New England District and are thought to indicate intermittent uplift in late Pliocene and early Pleistocene times (Browne 1969), so earth movements could have continued into more recent times. Unfortunately there have been no studies on the magnitude or timing of such movements and their effects on the stream terraces must remain hypothetical. The most likely factor is climatic control. Butler (1959, 1967) and other workers have suggested climatic changes to explain alternation between unstable phases of slope erosion and stream aggradation on the one hand and stable phases with soil formation and stream incision on the other. Butler (1967) suggests that the unstable phase is due to reduction in vegetation cover during a deterioration of the climate towards either drier or colder conditions, or both. In stable climates the vegetation can maintain its cover and slope erosion is reduced. Unfortunately there is not full agreement with this theory (see below).

The terraces in the area can be compared with similar terraces that have been studied elsewhere: in the Macleay valley by Walker (1970) and further south (e.g. Butler 1967). On the basis of relative position and soils the Qa_1 terrace at the caves would belong to the K_1 cycle and the Qa_2 terrace would correspond to K_2. The high level Qpa gravels may be remnants of an earlier K_3 cycle. Several authors have warned of the dangers of using K cycles for precise time correlations (e.g. Bowler 1967, and Young 1976). None the less, it is probably safe to make the general statement that the Qa_2 terrace (K_2) is of late Pleistocene or early Holocene age, while the Qa_1 terrace (K_1) is of Holocene age. Correlations between the terraces and the cave deposits are suggested later in this paper.

GEOMORPHOLOGY

Pike Creek is a tributary of the Dumaresq River and a part of the western drainage of the Border Rivers District which in turn is part of the Murray-Darling River system. The climate, though within the warm temperate (Cfa) class of the Koppen system is verging on the semi-arid (BSh) class. Mean annual temperature is 18.5°C, with a mean July temperature of 11°C and a mean January temperature of 24.6°C. The mean annual rainfall is 644 mm and 64% of this falls in the summer half of the year (based on data for the Texas post office; Bureau of Meteorology, 1975). The climate would appear to have fluctuated from more humid to more arid than the present during the development of the caves.

The area has a mature topography with strong relief: elevations range from 370 m A.S.L. in the valley floor up to 650 m on the crests of the main divides. Steep rocky slopes are common. The vegetation is generally open eucalypt forest.

The drainage has a moderately dense dendritic pattern. The valley of Pike Creek is generally less than a kilometre wide at its bottom and the greatest width is in the caves area, presumably because of the lesser resistance to erosion of the limestone lenses. Pike Creek tends to meander in the wider parts of its valley. The creek does not flow perennially but there are many permanent waterholes. Braided channels sometimes occur within the loose shingle deposits of its bed.

The limestone areas crop out much better than the other lithologies of the Texas Beds which are only exposed in stream cliffs and gullies. The karst morphologies of the limestones are the main interest of this report; the surface karst forms will be described first, and then the caves.

SURFACE KARST FORMS

The limestones show a wide range of surface karst forms. The most important features are the dolines or 'sinkholes', the most spectacular of which are the large collapse dolines of the Glenlyon system. The small scale solution sculpturing of the rocks shows a diversity of well-developed forms derived from both subaerial and subsoil solution.

THE DOLINES

THE GLENLYON AREA: There are about fifteen dolines in this area, ranging in size from small solutional forms to large collapse dolines up to 100 metres long and 8 metres deep, (see Maps 9 & 10). The collapse dolines were formed by the caving in of the roofs of underground chambers and their distribution indicates that the cave system was probably much more extensive at an earlier time. The two largest dolines, The Camp and Central Dolines (Map 9), act as karst windows exposing the underground stream which meanders across their floor, passing between them via a natural arch, and disappearing underground again before re-emerging on the banks of Pike Creek (see Map 9). The upstream end of the Glenlyon system, where the water from Pike Creek goes underground, is a collapsed stream cliff with large rotated blocks. The 'Briar Patch' (Map 9) is a shallow depression next to this collapsed cliff. It is regularly flooded by Pike Creek and has been largely filled with flood debris. The two 'cenotes' to the southwest of the Briar Patch are vertical collapse shafts containing water. They lie on a southwesterly continuation of the collapsed cliff. The collapse dolines sometimes coalesce to form composite forms; Crater Doline is the best example and has an irregular floor with three main depressions and a number of smaller ones (Map 9).

VIATOR HILL: Most of the dolines of Viator Hill are small solutional forms (Map 10) which have formed from the enlargement of several parallel or intersecting grikes. Sometimes there are vertical cave entrances or 'pot holes' within them. The size of the solution dolines varies from 2 to 10 metres across and up to 3 metres deep (excluding the depth of any caves or potholes). On the southeastern side of the hill there are several larger dolines of combined solutional and subsidence origin. The Main Cave entrance doline is a collapse feature at its western end, but the form of its eastern end is due more to subsidence and soil creep. Extending to the southeast from this doline are a line of three broad but very shallow subsidence dolines which extend across an area of colluvial cover (Map 10). They probably reflect the presence of an extension of Main Viator Cave along a subterranean drainage line leading towards Pike Creek.

THE WHALE ROCK AREA: This area contains only a few solutional and subsidence dolines (Map 10).

SMALL SCALE SOLUTION SCULPTURING

A great variety of small scale solution sculptures have been found in the area. The general term *karren* was applied to these features by Bogli (1960) who also described a number of specific types. English descriptive terms are applied here in accordance with the usage of Jennings (1971). The European equivalents are indicated in italics. Karren structures can be divided into two groups: the surface structures which develop from the solution of the bare rock outcrops by the action of rain water, and the subsoil structures which form from the solution of the rock beneath the surface by soil water.

THE SURFACE STRUCTURES: The most obvious of these are the grike fields *(kluftkarren)* and intervening clints which extend over much of the limestone outcrop area. These are solution trenches, which develop along joints or steeply dipping bedding planes. Where well-developed they can be over a metre wide and deep, and extend for up to 10 metres in length. They are separated by ridges of solid limestone of equal, but positive relief. The larger grikes often have an earth or rubble floor. Rain falling onto the grike fields is rapidly channelled underground and runoff from these areas is therefore negligible. Coalescing grikes can form small solution dolines and the concentrations of water inflow at these points would be a factor in localising cave development. Also common are solution flutes *(rillenkarren)*, which are narrow parallel grooves, separated by sharp edges, which run down sloping rock surfaces. At the top of an outcrop they can combine to form a sharp serrated crest. On more gently sloping rock surfaces solution pans *(kamenitsa)*, solution pipes, runnels *(rinnenkarren* and *maanderkarren)*, and some areas of rain pits are the usual forms. On vertical faces there are vertical rain solution runnels *(regenrinnenkarren)* and sometimes horizontal solution ripples. These last two features are also found in the vertical shaft entrances of some caves, together with small hemispherical pits which appear to be due to inflowing rainwater and may be analogous with current scallops. Current scallops are seen on the lower stream cliffs at Whale Rock, and would be due to solution by fast flowing flood waters.

THE SUB-SOIL SOLUTION STRUCTURES: These are generally less often seen in karst areas because they are soil-covered. However, in several places at the Texas Caves they have been exposed by stripping of the soil. They are characteristically smooth and rounded as distinct from the sharp-edged types formed at the surface. They include rounded depressions and networks of irregular holes in the rock) *(bodenkarren)* and rounded runnels separated by equally rounded ridges *(rundkarren)*. The best collection is seen in the Glenlyon area where they have been exposed by rotation of blocks adjacent to collapse areas, and subsidience of soil into dolines (Plate 3a). In the Whale Rock area the soil surface has been denuded by up to 40 cm in places and this has exposed a series of shallow horizontal notches which are probably related to solution by the acidic humus layer of successive levels of the topsoil.

THE CAVES

Although minor surface karst forms such as *rillenkarren* are found on most of the limestone outcrops in the region, major karst features, in particular caves, are only known in this area and at Riverton, about 10 kilometres to the south. This restricted distribution may be due to the larger than average size of these areas and their proximity to a large surface stream in each case: Pike Creek in the case of the Texas Caves, and the Dumaresq River (which may have been closer in the past) in the case of Riverton Cave.

Riverton Cave has not been included in this study. Its main importance is as a bat maternity colony for the region (Dwyer and Hamilton-Smith 1965; Dwyer 1966) and because it will become the sole remaining limestone cave in southeastern Queensland once the Texas Caves have been flooded. The cave has been mapped by the UQSS and a summary description has been compiled by Gillieson (in prep.).

The caves of the Glenlyon System are different in form and genesis from those of Viator Hill, and the two areas will therefore be described separately.

THE GLENLYON SYSTEM
(Map 9)

This system has formed as a subterranean cutoff of a meander spur of Pike Creek. The spur is 300 m across at this place but the underground stream follows an irregular route and is longer than this (see Maps 9 and 10).

The downstream half of the Glenlyon System has been largely destroyed by collapse which has formed the two large dolines at 080350 and 010340 (Map 9). Swallow Arch (040350) and The Dustbath (020370) are remnants of the old system isolated between the two dolines. Cloister Cave (120360), Efflux Cave (135345) and Cliff Pit (100334) are remnants on the downstream side of the collapse area.

To the west of the Central Doline the downstream part of the Glenlyon Stream Cave has also been modified by collapse. This has formed the large Crater Doline (950360) and a number of smaller dolines. The present southerly diversion of the underground stream may be due to blocking of a previous more direct route by the collapse of the Crater Doline.

The upstream entrance to the Glenlyon System has been blocked by the collapse of the cliff adjacent to Pike Creek (880440). This blockage has altered the hydrology of the system by restricting the inflow of water. The present underground stream is 'underfit' and the stream passages contain a considerable amount of silty sediment.

The system shows fairly strong joint control in the orientation of the cave passages (c.f. Fig. 1 and Map 8a). The main stream passages are now dominantly stream flow features: current scallops are common features and stream channel incuts and nitches can be seen on the walls in places. The side passages on the other hand retain some of their initial low energy phreatic characteristics: irregular networks, smoothly hollowed walls, bedrock blades, and flat roofs from the final shallow phreatic stage (Plate 4a, b). Some stream flow modification also occurs in these passages. Modification by breakdown has occurred adjacent to the dolines. Speleothem deposits are uncommon and are generally limited to the higher parts of the system where saturated waters are seeping into the cave and where the deposits are not reached by flood waters.

Studies of current scallops by Goodchild and Ford (1971) showed that the size of individual scallops decreases with increasing stream velocities. As velocity is related to the cross sectional area of the stream one would therefore expect smaller scallops in constricted parts of the cave stream passage. However, this relationship was not borne out by measurements in the upper part of the Sewer (919395) and in the Downstream Section (970341). Perhaps the scallops predate the entrance collapse and consequent siltation, and therefore are not in equilibrium with the present hydrological system. The presence of speleothems covering scallops in parts of the cave supports this view (Plate 3c).

The hydrology of the system will be discussed after the descriptions of the component caves.

GLENLYON STREAM CAVE (Maps 8a, b)

This is the major cave of the system. It comprises a main stream passage and a number of smaller side passages. The total passage length is about 1000 m. There are numerous entrances to the cave and the major ones have been numbered on the map. Most entrances are at the margins of collapse areas but a few vertical solution shafts form additional entrances in the Dry Crawlways and the Flattener. The stream normally enters the cave by one or more impassable routes from Pike Creek and leaves from the horizontal entrance GL-1E in the Central Doline.

The northernmost part of the cave is a maze of numerous small passages and chambers which occur between a jumble of large collapsed limestone blocks which form the stream cliffs. Only the lowermost passages (The Wet Section, 887435) and a major high level bypass route at 898440 have been shown on the map.

The Wet Section has a broad shallow pool of water generally 20–30 cm deep and with a silty to gravelly bed. A few mounds of sediment rise above the water in side passages. The rock walls and low ceilings generally show current scalloping. There are no speleothems.

The high level passages are all in rockpile, with smooth fractured surfaces and no current scallops. There is some flood debris near the lower entrances which provide inflow points during large floods.

The Dry Crawlways (860400) form a major offshoot to the west of the main Upstream Section of the cave. They are a network of low passages formed under phreatic conditions with joint control modified by stream flow. The roof is frequently flat and smooth with some scalloped areas and represents solution at an old water level. The walls are scalloped adjacent to the stream channels and sometimes show stream incuts. Elsewhere smoothly curved walls and cavities, together with limestone roof pendants testify to the dominantly phreatic origins. Blind shafts are common in the ceilings and generally contain abundant speleothem deposits. Several entrances in the southwest (e.g. GL-15E) have formed where shafts such as these have intersected the surface. Speleothem deposits are rare away from these blind shafts. Those few which are seen have been partly eroded.

There has been some collapse in the area between GL-14E and the pool at 854416. The north wall has subsided here. The pool connects via a water trap with the northern 'cenote' (C.H.C. Shannon, pers. comm.). and there appear to be water-filled connections between the two 'cenotes' and between them and the Wet Section to the northeast.

The Dry Crawlways contain a considerable amount of sediment; in places this forms mounds reaching to the roof (e.g. section 22 of Map 8b). The intermittent streams flowing through the passages have incised channels into the sediment. The deposits are mainly grey fine–sandy silts (Grimes, in prep.) but the beds of the stream channels also contain some sand and gravel, particularly in the upper parts. The chamber at 855411 has some rounded cobbles up to 20 cm in diameter. These must have been washed in at a time when there was easier access from Pike Creek.

The Upstream Section of the cave lies between 890430 and 920400. The northern part is commonly referred to as the Bat Chamber. Water from the Wet Section enters the Bat Chamber from a low horizontal slot beneath a large subsided block which forms the steeply sloping north wall of the chamber. The fissure above this block opens to the surface to form several daylight holes, including entrance GL-2E. This fissure also extends to the southwest where it provides access to the Dry Crawlways and to the northeast where it joins to the irregular high level section.

The main stream passage in the Upstream Section is about 10 m wide and 2 m high. The roof is a flat solution plane in some places (e.g. section 4, Map 8b) but is generally arched (section 5 and Plate 3b). There are a few blind shafts with minor speleothem development. A few hanging rock projections occur at the downstream end of the passage. The rock surfaces have a finely pitted surface (hemispherical pits about 1–2 mm across) with a network of narrow etch grooves (1–2 mm wide and up to 5 mm deep). These grooves may be due to etching of veins or small factures. In some places beads of water are seen along the grooves which could indicate the existence of water seeping along fine cracks and becoming aggressive on exposure to the cave air.

The walls of the main passage are generally not well-exposed as they are hidden by mounds of sediment which reach nearly to the roof (Plate 3b). Stream incuts, meander niches, and scallops are seen where the gently meandering stream comes up against the walls.

Two narrow side passages extend off the northeast and are developed along vertical joints. The eastern passage terminates in a talus choke which is located beneath a small surface doline at 920435.

Throughout the cave the sediments are typically interlaminated dull yellowish brown (10 YR-5/4) fine sand and brownish black (10 YR-2/3) silt and mud. The laminae vary from 1 mm to 5 mm thickness and tend to lens in and out. They dip parallel to the present surfaces of the mounds.

The stream passage bifurcates at the downstream end of this section (919397). A small low-level passage, The Sewer, takes the present stream. To the north is the Flattener, which must originally have been the continuation of the main passage but is now almost entirely silted up.

The Sewer (924380) has the form of a pressure tube with smoothly curved walls and scalloped surfaces. Its diameter is much smaller than that of the main stream passages of the cave. A number of bell-holes rise above the general ceiling level. These are unscalloped and contain some speleothems. Plate 3c shows a view of the Sewer with small ribbons descending from a bell-hole and covering the scallops of the wall. The stream flows over soft silt with some gravel present at depth. The sediment apparently contains organic materials, as bubbles of an inflammable gas were released when the desposit was probed with a metal rod.

The Flattener (935395) is characterised by a gently inclined ceiling which has a more or less flat surface at the same level as the upstream section and an earth floor which lies generally less than half a metre beneath it. At its eastern end a vertical solution shaft in the ceiling reaches to the surface (944385) and a second but blind shaft is found in the same area (see Profile P-3, Map 8b). The Flattener is terminated at this end by a vertical fissure and a rockpile wall adjacent to the Crater Doline. A narrow passage adjacent to the rockpile is all that remains of the connection to the downstream end of the Sewer. There is an entrance (GL-16E) and several small daylight holes in the rockpile. The original form of The

Flattener was probably similar to the stream passage above and below this section, but it became filled with sediment after partial blockage by the collapse of the Crater Doline which allowed The Sewer to capture the main stream flow.

The Middle Section (915350) is similar in form to the Upstream Section. The main differences is that for the northern part of the section the eastern wall is composed of rockpile adjacent to the Crater Doline. GL-17E is the largest of several entrances through this rockpile. In this part the stream runs adjacent to the solid western wall and has formed scallops and some deep incuts in the wall (section 10, Map 8b). Further along this passage the stream meanders between sloping banks of sediment. The Middle Stream terminates in rockpile at its downstream end, with a large entrance (GL-18E) leading in from a doline at 920327.

The Rockpile Section (930325) consists of an irregular network of small passages and cavities between collapsed blocks. This part of the cave is consequently ill-defined and the mapped boundaries are only approximate. The stream water appears as occasional pools in the lower parts of the rockpile. Many of the lower blocks show current scalloping. In places smaller boulders and cobbles are held together by a dark grey clay matrix.

The Downstream Section (960330) is composed in its upper (southern) part of a series of interconnected, low, wide passages with many bedrock blades projecting from roof and walls, rock pillars, portholes, and solutionally enlarged joint fissures. Current scalloping is common, except in the higher parts where there are small etch grooves of the type described from the Upstream Section. There are a number of fallen blocks on the floor. This section would appear to have been a phreatic network now largely disrupted and modified by stream action.

Further downstream (north), past a collapsed section with the entrance GL-19E (963316), the stream flows into a wide chamber. At the southern end of this chamber the ceiling is a smooth and flat solution surface or has broad rounded concavities (30–50 cm wide and 5–10 cm deep). There are a number of blind shafts 1–2·5 m wide and up to 1·5 m high. The largest of these has a honeycomb form. Further north the roof is largely made up of fracture surfaces resulting from collapse. The walls of the chamber are scalloped up to two metres above the stream level. There are some small stalactites and ribbons.

The stream meanders across the floor and undercuts the wall at the northern end of the chamber (971337). The silty to fine sandy sediment forms mounds reaching nearly to the ceiling.

A high level extension at 965317 is in rockpile beneath the surface doline. Some small extensions from the main chamber at 973330 have phreatic features and show joint control.

Downstream from the large chamber is a narrow, arched stream passage with several large bell-holes. Walls and ceiling are strongly scalloped. This passage leads to the downstream entrance (GL-1E, at 980345) which is at the end of a small daylight chamber. There are collapsed blocks on the northern side of this chamber but a solid limestone wall forms the southern side and is marked by scallops and has several stream meander niches.

Two entrances in the Crater Doline (GL-20E and GL-21E) lead to a group of interconnected passages and small chambers which finally connect with the main stream passage. The largest chamber (966355) has a high roof extending into a small daylight hole. The other two chambers (964350 and 970349) have several blind shafts which contain flowstones, cave coral, and ribbons. The walls in the lower parts of this section have scallops. Elsewhere they are often marked by phreatic pockets (Plate 4a).

NETTLE MOAT CAVES (GL-10 and GL-11; 990320 and 995300, Map 9)

Though originally described as a single cave (Toop, in prep.) the Nettle Moat is actually two caves connected by the deep collapse doline at 985308. Mapping of the Nettle Moat Caves by UQSS was still in progress at the time of writing. The outline shown in Map 9 is reduced from a preliminary field compilation.

The northern cave (GL-10) is entered horizontally from the base of the doline. An eastern collapsed section, which lies beneath the edge of the Central Doline, is made up of several rockpile chambers with occasional daylight holes. The western part of the cave is composed of a number of small, joint controlled passages and chambers. There are a number of high blind shafts with speleothems. The sediment floor is irregular and there are steeply sloping mud floored passages which become impenetrable at their lower ends. A small, normally dry, stream channel indicates flow through this section and out of the entrance into the doline where it terminates in a small depression. The water feeding this channel appears to come from the Glenlyon Stream Cave during floods. It probably enters through one or more of the sloping passages. The rock walls are scalloped in some places; elsewhere they are smooth or fractured. There is some intricate phreatic sculpturing: blades, portholes, and small tubes being the most common forms.

The southern cave (GL-11) has a horizontal entrance in a small overhang in the side of the doline. This cave is basically a low, wide passage which enlarges into a small chamber in one part. There are several daylight shafts and much of the cave is in semi-daylight. Ceilings and walls have many fracture surfaces but solutional surfaces are equally common. Speleothems are moderately abundant: cave coral, short conical stalactites, some short straws, smooth flowstone coatings and ribbons. The flat floor is of earth and rubble.

THE DUSTBATH (GL-6; 020370 Map 9)

A detailed description and map of this cave has been published elsewhere (Grimes and Brown 1976).

The Dustbath is a remnant of stream passage isolated by collapse of the Central and Camp Dolines. There are horizontal entrances (GL-6E and GL-22E) below cliffs at either end of the old stream passage. A third vertical shaft entrance (GL-23E), to the north, has formed above a higher level rockpile chamber.

The rockpile chamber connects to a smaller bedrock chamber, which has some small, but well-formed ribbons and to a low, flat-roofed passage (Plate 4b) which leads down to the old stream passage.

The stream passage is almost completely filled with silty sediments and in this way is similar to The Flattener Section of the Glenlyon Stream Cave. The roof is more or less flat and current scallops are common both on it and on visible parts of the walls (Plate 4b). Blind shafts and joint controlled fissures rise above the general level of the roof. These often contain speleothem deposits.

Cave coral is found in places throughout the cave, as are etch grooves of the type recorded from the Glenlyon Stream Cave. In one place (Plate 4c) these etch grooves show a progression in development from isolated narrow grooves (1–2 mm wide and several mm deep) through larger but still discrete grooves (up to 1 cm wide and several mm deep) and finally to a coalescing hackly surface with only a few raised remnants of the original smooth surface (Grimes and Brown 1976). The cause of this progression seems to have been a slight case-hardening of the surface so that solution was most active on the walls of the grooves, which therefore retreated across the surface.

SWALLOW ARCH (GL-3A; 035345, Map 9)

The arch is a low, wide remnant of a stream passage which passes beneath a narrow wall of limestone separating the Central and Camp Dolines. The cave stream flows through the arch. Swallow Arch has a span of about 13 metres but it rises only 2 m above the water at its highest. The limestone cliffs rise 9 m above the stream and the wall is only 3 m wide in places at its top. The stream flows diagonally beneath the arch, between sloping banks of grey silty sediment. The walls and roof are strongly scalloped. Several blind shafts rise into the roof and contain cave coral and large rounded masses of moss covered speleothem material which could be old eroded stalactites. There is an isolated horizontal tube above the main level on the southern side of the arch. This is about 1 m in diameter and strongly scalloped. A map of the arch is held by the UQSS (see Appendix 2).

CLIFF PIT (GL-9; 100335, Map 9)

A vertical shaft entrance leads to a joint controlled fissure-like passage. There is a low-roofed horizontal extension to the south and the roof of the fissure passage to the north becomes lower until it ends in a muddy crawlway which often contains water. There appears to be a hydrological connection with Cloister Cave. The lower parts of the fissure passageway have slightly weathered scallops. Narrow tubes and pockets in the wall and ceiling appear to be phreatic forms. Speleothems are absent except for some smooth wall coatings. Near the top of the entrance shaft there are some narrow horizontal solution ripples which would be due to rainwater inflow. A detailed map is held by the UQSS (see Appendix 2).

CLOISTER CAVE (GL-7; 120360, Map 9)

This stream cave originally known as 'The Downstream Section', (e.g. Shannon 1968), is basically a deep undercut of the cliff above it with the outside walls formed by large subsided blocks. The stream flows in a horizontal entrance

(GL-7E) at the southwestern end, and a pool follows the inner wall around to the eastern end of the cave, where the water passes through a submerged passage and emerges in a pool in the adjoining part of the Efflux Cave (Brown 1970b). Brown (op. cit.) reports an air pocket within this section which contained a gas composed of Nitrogen (89.6%), Methane (7.3%), Oxygen (plus Argon) (2.0%), and Carbon Dioxide (1.1%). This mixture is probably derived from the decay of organic material in the sediments. The composition of the gas in the sediments of the Sewer (see above) may well be similar.

There are several inclined entrances through the rockpile on the western side and from a small subsidiary doline to the north (GL-25E). As a consequence much of the cave is in semi-daylight. The pool occupies much of the floor; the remainder is a steeply sloping bank of silty sediment and flood debris. The walls and ceiling are strongly scalloped. Some calcite (?) veins have been etched out in positive relief above the upstream entrance and now stand out 2–3 cm from the surface. A detailed map is held by the UQSS (see Appendix 1).

EFFLUX CAVE (GL-8; 135345, Map 9)

A low, wide, horizontal entrance in the base of a cliff is the edge of a broad but low semi-daylight chamber which represents the bulk of the cave. The roof is generally 1 m or less above the floor. The roof and walls are scalloped and there are some tubes, blades and small bridges in the ceiling; all are scalloped and sharp edged. There is some V-section enlargement of irregular joints in the ceiling. The floor is gently sloping and silty with minor gravel and some heaps of flood debris. At its northeastern end the floor slopes steeply where flood waters are eroding an earth bank.

The stream enters the cave via a submerged passage from Cloister Cave (Brown 1970b) and rises in a pool at the back of the chamber. From there it flows along the southern wall and out of the entrance. It follows a narrow channel to a permanent waterhole in Pike Creek about 15 m away but goes underground briefly at two points before reaching the creek. The first of these is where the stream flows beneath a large subsided limestone block and the second is where it used to be bridged by an earth mound (C. H. C. Shannon, pers. comm.). This bridge has now collapsed and blocks the stream channel so that the present flow must be through cavities in the earth bank of Pike Creek. A detailed map of the cave and the stream course is held by the UQSS (see Appendix 1).

THE 'CENOTES' (GL-26 and GL-27; 849420 and 845417 respectively, Map 9)

These are two vertical shafts in rockpile with shallow pools at their bases. There is hydrological connection with the Dry Crawlways and also with Pike Creek (possibly via the wet section of the Glenlyon Stream Cave). They have not been mapped at the time of writing.

HYDROLOGY OF THE GLENLYON SYSTEM

The Glenlyon System is an excellent example of a subterranean cutoff of a meander loop; a feature of karst areas which has been discussed in some detail by Thornbury (1954). It appears to be the only Queensland example of this form of subterranean drainage.

Complete capture of the surface stream has not occurred. This is probably due to successive collapses of various sections of the cave which restricted the through-flow of water so that downcutting by the surface stream could keep pace with cave development.

At normal stream flow levels the inflow point for the cave stream is not obvious. Gillieson (pers. comm.) reported an inflow of water into a small fissure in the bank of Pike Creek (910471, Map 9) which became visible at a time of low water. A small passage was seen beyond this fissure but has not been explored. Within the cave the water cannot be followed upstream beyond 888438 in the Wet Section where it emerges from beneath subsided blocks. In places around the edge of the Briar Patch (880440) small pools of water can be seen through openings in the rockpile of the cliffs, and it is likely the water from the influx fissure reaches the cave by flowing through small cavities between the subsided blocks. A hypothetical route is shown on Map 9. Some water may also reach the cave by percolation through the sediment banks of Pike Creek.

Standing water is also found in the two 'cenotes' and in the pool at 854416. An underwater connection is known between the pool and the 'cenotes' and presumably water reaches them by flowing either through rockpile from the Briar Patch area, or by direct percolation from the creek.

The shallow depression of the Briar Patch is filled with water during major floods and this water then enters the cave directly through passages in the rockpile of the cliffs.

Within the Glenlyon System there is a semi-permanent stream which follows the underground route shown on Map 9. In dry seasons the lower end of this stream dries up and on occasions the channel has been dry all the way up to the pools of the wet section.

An additional stream channel, which only carries water during floods, starts at the pool at 854416 and passes through the Dry Crawlways and into the Upstream Section. A tributary branch starts in an inaccessible extension at the southwestern end of the Dry Crawlways. This tributary may merely be the result of draining of back waters after a flood, whereas the main branch is fed by water welling up from the pool.

At the downstream end of the Stream Cave an overflow channel carries flood waters into and through the northern Nettle Moat Cave.

The normal stream flow rate through the Glenlyon System is between 10 and 20 litres per second (l/s). Flood debris within the cave shows that the passages fill completely during major floods. During small floods the cave stream shows only a small response to changes in flow rates in Pike Creek. In February 1975 the author observed a small flood in which the flow in Pike Creek rose from less than 1000 l/s to a peak in excess of 25 000 l/s. At the same time there was only a slight increase in the underground stream flow: from 14 l/s to 26 l/s. Shannon (1964) reports similar observations for a larger flood of 40 000 l/s in Pike Creek, with less than 60 l/s in the cave stream. At the peak of the 1964 flood a small flow occurred in the upper part of the Dry Crawlways channel, and there was water in the Briar Patch. Water had started to enter the cave through the rockpile entrances in the base of the cliff, and the underground stream flow rates could be expected to increase more rapidly for flood levels higher than this. The cave stream has a larger flow after floods, and then diminishes. This is probably due to flushing of the system during the flood, followed by accumulation of debris in the inflow area.

The gravels beneath the present stream bed, and the cobbles and gravel at the upstream end of the system probably remain from an earlier period of stronger flow which existed prior to the collapse of the upstream cliffs. The current scallops on the passage walls may also date from that earlier regime.

THE LARGER CAVES OF VIATOR HILL

Viator Hill has two large caves (Russenden Cave (VR-2) with about 500 m of passages, and Main Viator Cave (VR-1) with 200 m of passages), 14 smaller named caves and potholes, and a number of small unnamed pots (vertical shafts with minimal development at the base). The larger caves have horizontal development on one or more levels related to old water levels.

MAIN VIATOR CAVE (VR-1; 251293 on Map 10)

Maps 1a and 1b provide detailed plan and sections of the cave. This cave has also been known as 'Cathedral Cave' and 'Old Cave' (e.g. Shannon 1968). It has been visited regularly since late in the late century (see Robinson 1978). During the February 1976 flooding in the region water backed up from the nearly completed dam and the cave was submerged for several days. When the water drained from the cave several new extensions were opened up. These have been mapped and described by the UQSS (Shannon 1976a, b), whose plans of the new sections are incorporated in Map 1a.

CAVE MORPHOLOGY: A horizontal entrance (VR-1E – Map 1) leads in from a doline at the base of Viator Hill. There are four daylight shafts which open into the roof of the cave (VR-12E, -13E, -19E, and -22E). From the main entrance a sizable passage leads to a large chamber about 50 m long and averaging five metres in height. This chamber forms the bulk of the cave. A lower side passage extends off to the northwest and a newly discovered passage extends to the northeast. The walls show horizontal solution undercuts at several levels related to old standing water levels (Plate 5a). The three best developed levels are at about 384·0 m, 382·4 m and 381·4 m A.S.L. (a, b, c on Map 1b).

The main entrance (VR-1E) has a low roof composed of horizontal flowstone, reddish and coarse grained, overlain by a massive red earth breccia with some bone fragments.

Beyond the entrance the passage opens up into an antechamber about 11 m long and 5 m high with an inclined shaft from the ceiling leading up to a daylight hole (VR-19E). The walls and ceiling are of limestone with minor red earth breccias. The floor is mainly made up of rubble and large fallen limestone blocks. Some subsidence occurred here after the February 1976 flooding. At the western end of the chamber there is a finely crystalline white flowstone with microgoured surface. Flowstones of this type are found throughout the cave and will be designated as the 'younger flowstones' as they are better preserved and in places overlie the reddish coarse-grained flowstones (such as the one already mentioned at the entrance); these latter will be designated as the 'older flowstones'.

A low roofed section of the cave extends to the south from the antechamber (540915, Map 1). The roof here is flat and is related to the lowest solution level of 381·4 m. The floor here is a dusty brown earth. A normally dry stream channel leads from the main entrance and meanders across this floor to a shallow depression.

Beyond the antechamber is a second low-roofed section at 534928. The low roof here is mainly composed of red earth breccia with interbedded 'older' red flowstones. The breccia consists of angular fragments of soft red-brown clay in a matrix of light brown moderately hard calcite tufa. The limestone walls here are pitted with hollows 1–2 cm wide and 1 cm deep. The floor is covered by large fallen limestone slabs.

This low section leads to a high-roofed offshoot from the main chamber at 526932. A daylight hole (VR-22E) opens into the roof. A large 'old' red flowstone, about two metres thick occurs high up on the north wall and continues into the main chamber at 526937. Solution undercuts of the 381·4 m and 382·4 m levels occur on the south wall. A small dry stream channel starts here, formed by rain water entering the daylight hole, and leads into the main chamber where it ends in a pit at 514934.

The main chamber is elongated along a 060° striking fault and joint line. The roof is arched and varies from five to eight metres in height. The walls and roof are of solid limestone with irregular areas of a brecciated limestone with a hard grey lutite matrix occurring between the fragments. This lutite breccia is also found in the surface outcrops (see above), and predates the formation of the cave; it probably dates from an earlier tectonic episode. The floor of the chamber is covered by rock debris at its southwestern end but elsewhere is composed of compact grey-brown earth (see later discussion of sediments). The floor has an irregular surface with several shallow pits which may be relicts of old guano mining activities.

At its northeast end the chamber narrows to a sharp angle developed along a fault zone in lutite breccia. There is evidence from drag effects that the northern (solid limestone) block has moved up relative to the southern (lutite breccia) block. West of here the north wall has two well-developed solution undercuts: the 381·4 and 382·4 m levels (Plate 5a). These two levels are not as well-developed on the south wall, although a higher (384 m) level can be seen on that side.

The high dome in the centre of the main chamber (505927) has a daylight hole (VR-12E) on its northern side. Below this hole is an 'older' weathered red flowstone which is overlain by a 'younger' white flowstone that forms a large compound canopy and a large (2 m) stalactite. The floor below has some large fallen blocks and a few squat 'younger' white stalagmites.

In the southern wall near this dome there is a low alcove behind a corroded old flowstone projection at 503920. Inside the alcove there is a 'younger' white flowstone with some well-developed gours on the floor and a coating of white crystalline cave coral on the back wall.

At the southwestern end of the large chamber there is another daylight shaft (VR-13E) and this also has a massive development of both 'older' coarsely crystalline flowstone and 'younger' finely crystalline flowstone. The old flowstone has individual calcite crystals up to 5 cm long and 3 cm wide. It does not occur below a level of 384·7 m (1·5 m above the present floor) in this area, and has a horizontal 'bedding' in its lower parts. This suggests that it formed above an old floor level, since removed, which predated the 'younger' flowstones and the present floor deposits. The horizontal 'older' flowstones in the entrance areas of the cave are probably also related to old floor levels, although they are lower (382·3 m) than at the western end of the cave.

The walls of the main chamber are irregular in form but generally smoothly surfaced with a powdery weathering film. They are sculptured by elongated V-notches up to 10–15 cm deep and 10 cm wide which are developed along joints. There are also large irregular hollows and the undercut levels mentioned earlier. Fine sculpturing effects include areas of pitting (with hemispherical pits 0·5 to 2 cm across) and small etch grooves (0·5 to 1·0 cm wide). One example of indefinite, shallow, vertical runnels was seen on an overhanging wall.

The largest new section disclosed by the February 1976 flooding starts from a subsidence pit which formed in the floor of the main chamber at 514937. From the bottom of this pit a low passage extends to the northeast beneath a bedrock roof. There was a small pool at the lowest point which has since risen in response to the rise in Pike Creek. From there the passage rises and becomes larger until it opens into a chamber at 535954. The sloping passage has solution undercuts on its wall which slope at the same angle as the passage, which suggests pressure flow in a water filled tube at the time of its formation.

Hollows in the walls up to 30 cm across could be the remnants of large scallops.

The chamber at 535954 has a flat roof at an elevation of 384·3 m and 5 m of head room at its western end. The earth floor rises to the east so that it is only 1·2 m below the roof at the far end of the chamber. Tree roots and carrot shaped stalactites hang in several rows from the ceiling and there are some stalagmites and small areas of flowstone on the earth floor. The chamber ends in a fissure that is largely filled by collapsed rubble. A few short passages can be followed into this rockpile.

The entrance to the main side passage (495940) which runs to the northwest from the main chamber, is not well-defined because the roof drops in several steps and the walls converge gradually. Further in, the roof is only 2–3 m above the floor and in places is a flat surface related to the 381·4 m level. Elongated blind shafts rise up to 3 m into the ceiling, and are developed along the joint which controls the passage direction. At its far end the passage becomes low and narrow and terminates in an earth filled squeeze. The earth floor of the side passage is much damper than the main chamber and there are many drip points in the roof.

Two large white finely crystalline columns and associated 'younger' flowstones occur at 487950 in association with a high, steeply inclined, fissure at 491949. Some 'older' coarse flowstone remnants occur on the wall behind the columns. A cone of red earth descending from the fissure contrasts with the chocolate-grey earth of the floor elsewhere. The fissure is choked at the top by red earth. Its hanging wall has symmetrical scallops 1–3 cm in diameter and 1 cm deep with sharp edges. Similar features have been seen in the entrance shafts of some of the pots and they are presumably due to solution by water trickling down the surface. One side of the fissure is plugged by a soft white to pale brown sintery deposit.

The flat roof in the vicinity of section 8 is related to the solution level of 381·4 m. In general the roof and walls of this side passage are much more irregular than the main chamber, due to numerous large hollows (up to 30 cm wide and of similar depth) which give a honeycombed appearance in places. Fine texture superimposed on these features includes sharp edged shallow to hemispherical pits 1–3 cm across and up to 1 cm deep with micro-pits 2 mm or less developed on top of them. Brown surface stains are common and probably indicate bat roosts. The surfaces are clean, sharp edged and often damp, in contrast with the main chamber which has rounded powdery surfaces. There are numerous drips in this section but little dripstone apart from the large columns which are related to the fissure. This suggests that the waters are undersaturated and therefore aggressive which would explain the honeycombing effects. By contrast the large columns would have been deposited from saturated waters entering via the fissure.

The February 1976 flooding also opened up a new extension that is a continuation of the side passage from 482959. A small tunnel with a muddy floor slopes down from the floor of the side passage and leads to a pair of small low chambers with sloping floors and a final flat section which eventually becomes too tight to penetrate. The walls and ceiling are generally irregularly pocketed but there are flat ceilings in places which could indicate old water levels. There is a clump of helictites up to 5 cm long above a small alcove with a flowstone floor at 475968. The form of the earth floor suggested a strong outward flowing current (Shannon 1976b).

A line of shallow depressions extends to the southeast from the entrance doline of the cave. These could be shallow subsidence dolines above an unpenetrated and possibly earth filled extension of the cave system leading towards Pike Creek.

THE SEDIMENTS OF MAIN VIATOR CAVE: Sediments described here were exposed in a shallow UQSS excavation at 512927, and noted in six auger holes (MA-1–6) drilled by the GSQ and the UQSS. Detailed logs, and physical and chemical properties are tabulated in Grimes (1977) and summarised below. Localities are shown on Map 1 and a section in Fig. 2.

The sediments which form the floor of the cave have a considerable depth, exceeding 6·5 m in MA-6, and occupy more than half the original volume of the cave. The red earth breccias have been described already; they lie above the general floor level and are different in character to the floor deposits. They would appear to have formed and later been eroded prior to the formation of the present floor deposits. They are contemporaneous with the 'older' flowstones.

Mechanical analysis suggests that the floor sediments are dominantly very poorly-sorted silts. The poor sorting is due mainly to the common occurrence of clay aggregates of granule to small pebble size in the coarse fraction, and of a substantial percentage of non-aggregated clay in the fine fraction. Other components of the coarse fraction are small angular fragments of limestone and of grey lutite (both presumably derived from the walls of the cave) and small calcareous nodules and cemented particles which may be diagenetic. There is an overall trend from coarser mean grain sizes in the upper parts to finer means at depth. This trend may be partly of wholly due to progressive destruction by compaction of the clay aggregates in the deeper levels, or destruction of the aggregates during augering because the lower sediments were generally wet and plastic, and sometimes quite sloppy.

The acidity of the samples was tested with the CSIRO Soil pH Kit which uses a colour indicator and comparison with standard colour chips at pH intervals of 0·5. There was a general trend from strongly acidic near the surface (pH values as low as 3·0) to mildly alkaline at depth (pH up to 8·5). Details are given in Grimes (1977). The acidity near the surface may be due to decaying organic material together with bat droppings and urine deposited on the surface, the downward seeping acids being neutralised by carbonate waters at depth.

Phosphate and carbonate contents of the sediments were estimated by spot tests using an acid solution of ammonium molybdate. Phosphate was estimated by the presence and intensity of the yellow colour, and carbonate at the same time by the degree of effervescence. Details of these subjective estimates are listed in Grimes (1977). The only strong phosphate reaction was from the unit 5 material immediately above a presumed speleothem deposit at the base of MA-4; similar material at the base of MA-5 gave a moderate reaction. Weak to moderate phosphate reactions were obtained from units 1 and 2, but unit 3 was mostly negative. In all over one third of the samples tested were negative.

Carbonate was detected in only a quarter of the samples tested and most of these gave only weak reactions. The strongest reactions were from the deposits immediately above the presumed speleothems at the bottoms of MA-4 and MA-5, and from unit 1 in MA-6.

The sediments are mostly massive but show variations in colour and in the amounts and types of clay aggregate present. Often changes are difficult to correlate between holes but three main units and two subsidiary units can be recognised (Fig. 2).

Unit 1 is the surface deposit and varies from 30 cm up to possibly 1·7 m in thickness. It is a medium to dark grey and chocolate earth (5YR2/2 to 4/4) with varying proportions of clay aggregates. Small sand sized chips of limestone, lutite, and charcoal (?) are sometimes present.

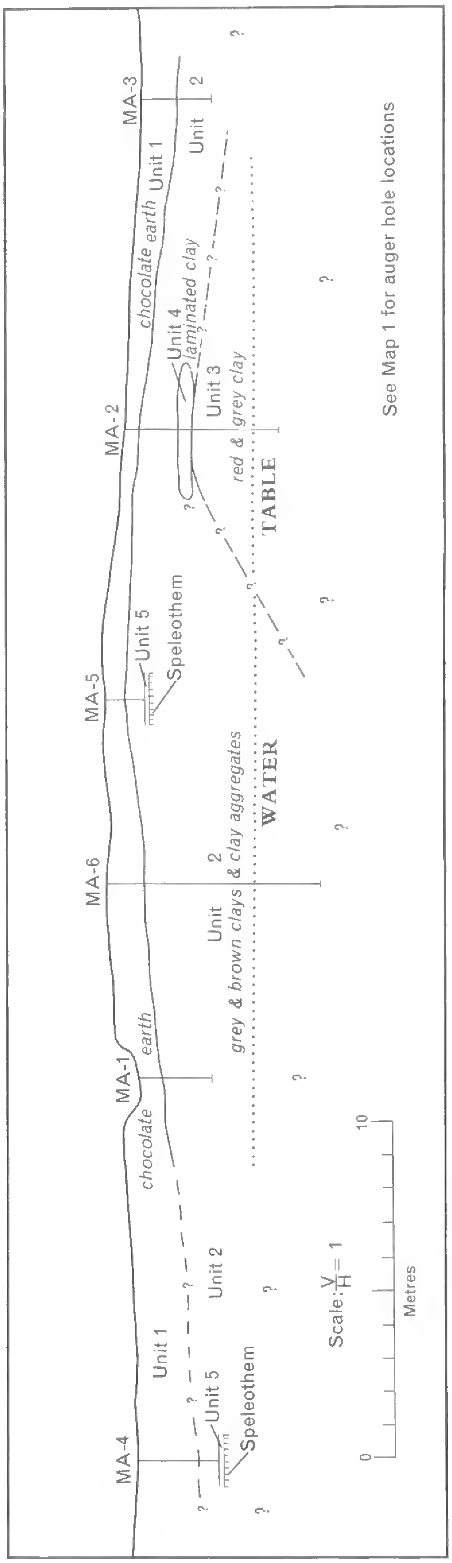

FIG. 2: Distribution of sediments in Main Viator cave.

The top decimetre or so has been compacted by visitors feet but below this it has a massive earthy structure. Median grain size averages 4·8 ϕ, in the coarse silt range. The material is extremely poorly sorted. The pH varies from 3·5 to 6·0, averaging 4·7.

Unit 2 is the thickest unit. It is quite variable in character with several recognisable subunits which however, cannot be correlated between holes. The thickness varies from 1·3 m to greater than 5·5 m. The texture varies from a loose earth to a compact clay. The clay aggregate content varies from a mere trace up to nearly 100%. Detailed lithologies are given in Grimes (1977). Brief descriptions of the major subunits follow:

The upper part of the unit seen in the UQSS Pit, and in MA-1, MA-2 and MA-5 is generally a medium to light grey clay or earth (5 & 10YR 3/3–4/2–6/1–7/2) with white flecks, dark spots of charcoal (?) and varying amounts of pale-grey, yellow-brown, and occasionally orange-brown clay aggregates ranging from granule size up to 4 cm. Interbeds of darker chocolate earth occur. In MA-3 the unit is a dark grey clay with aggregates. The lithology in MA-6 is of a richer brown colour (10YR 5/5–5/4–4/2), has a lesser proportion of clay aggregates, and reaches a much greater depth (6·45 m).

In MA-4 unit 2 is represented by an earthy deposit with an overall dull reddish-brown colour (5YR 4/3) which is composed almost entirely of multicoloured clay aggregates ranging from granule size up to 3 cm. The aggregates vary in colour; dark grey, yellow-brown, red-brown, light grey and chocolate coloured particles being present. The average size of the aggregates decreases with depth and the overall colour becomes lighter (5YR 6/4). The unit is phosphatic.

A similar multicoloured aggregate deposit is found between 1·1 and 1·5 m depth in MA-2. The overall colour is more yellowish (10YR 5/2–7/4).

A mottled yellow-brown (10YR 5/5) and light olive grey (5YR 6/1) clay subunit with no aggregates occurs as a bed between 2·4 and 3·0 m in MA-6.

Unit 3 is found only below 2·0 m in MA-2, though it could underlie MA-3 which was only a shallow hole. In its upper parts it is a mottled and streaky red-brown (10YR 4/4) and pale grey (5YR 8/1) pure plastic clay with occasional hard chips of red-brown claystone (the latter possibly derived from thin consolidated beds). At depth the colour becomes more uniform. There is a zone of grey-brown clay (5YR 4/5) between 2·9 and 3·5 m depth. The streaky patterns in this unit may be due to distorted clay aggregates in the plastic clay. The unit continues to the bottom of MA-2 (depth 4·55 m) but is absent from the deeper hole MA-6 to the southeast. It may be equivalent to the red earth of the cone beneath the fissure at 491949. The appearance of the unit is similar to that of unit F in RA-2 in Russenden Cave. An X-ray analysis of the unit's clays indicate the presence of both kaolin and illite.

Unit 4 is a localised but distinctive lithology found between units 2 and 3 at 1·6–2·0 m in MA-2. It is a hard, finely laminated medium to dark yellow-brown (7·5 Y 7/4) siltstone and claystone. The laminae are straight and even, and vary between 0·1 and 1·0 mm thickness. The thicker laminae appear to be graded. This unit apparently was deposited in calm water under fluctuating source conditions.

Unit 5 is a local facies found at the base of MA-4 and MA-5. Thin beds of powdery, spotty, white, black and brown clay and tufa-like material overlie hard rock which is thought to be speleothem material as a few calcite cleavage fragments were recovered. Whether the (presumed) speleothems overlie bedrock or further sediments cannot be determined, though the latter would seem likely in the case of MA-5 which lies between the two deep holes, MA-2 and MA-6.

RUSSENDEN CAVE (VR-2; 225301 on Map 10)

This cave (see Map 7 for details) was discovered by the UQSS in 1967 after excavation in a shallow doline (Bourke 1975). Its two entrances (VR-2 and VR-14) are on the western side of Viator Hill and only 70 m from the old stream cliffs and Qa_2 terrace on the edge of the hill (Map 10).

CAVE MORPHOLOGY: The cave has developed two main levels; the upper level contains considerable speleothem deposits, including some excellent canopies, columns, flowstones and shawls. The lower level is less extensive and contains foul air in late summer (see gas analysis in Brown 1970a). The chambers in both levels are floored by a considerable thickness of sediments. Bone beds have been excavated in the upper level (see Archer 1978).

The main entrance (VR-2E), 252011 on Map 7, is a tight opening in rockpile at the top of a steeply sloping passage in solid rock which leads down to the Main Chamber. A talus cone has been built up in the main chamber below the entrance.

Main Chamber (260017 – Map 7, Plate 5c): This chamber is about 25 m long, 10 m wide and 3 m high, with two large passages and a smaller one leading from it. The ceiling is horizontal at a level of 390·8 m (Profile P-2, Map 7), though in detail its surface is quite irregular with many small pockets (from 5 to 50 cm across and half as deep) and fissures rising above the general level (Plate 5c). The roof of the entrance passage continues as an inclined fissure in the main chamber ceiling (Profile P-2). There are massive flowstone canopies on the foot-wall of this fissure and these spill into the chamber below as a line of large stalactites.

The walls here and throughout much of the upper level of the cave are smoothly curved to irregular with V-notches along joints and many shallow hollows and pockets. The surfaces are smooth to roughly textured and have a white powdery film. Fossils in the limestone are sometimes etched out in slight positive relief.

There are several low alcoves and small subsidiary chambers about the sides of the Main Chamber. One in the western wall (248017) has its entrance partly blocked by two vertical bedrock blades which are joined by a flowstone mass. An impressive row of stalactites, stalagmites and large columns follow the western wall north from this grotto.

The floor of the main chamber is horizontal and composed of a dark red-brown earth, with some rocks in and near the entrance talus cone. Augering has indicated depths in excess of 5·5 m, so more than half of the original chamber has been filled by sediment. A large natural pit 1·8 m deep in the floor at 252027 is due to subsidence. This may open either into an open cavity at depth or be due to continuing solution of the bedrock beneath the sediment. Shannon (1972) considers that these pits may be due to simple compaction of the cave sediments over buried shafts in the bedrock floor.

At the eastern end of the main chamber the floor has been eroded as much as two metres by water running down into the passage which leads to the lower Foul Air Chambers. Here there is an old guano pile (271017) with a thin cemented capping (see discussion in sediments section).

A short side passage to the north of the main chamber is basically a continuation of that chamber. There is a high blind shaft in the roof above the auger site RA-4. A short low-roofed side passage leads to the Red Earth Section (241030).

The Red Earth Section is a large, joint controlled vertical fissure passage 20 m long, 2-3 m wide and up to 6 m high. A low roofed extension continues on from the southern end. The ceiling is arched with many large stalactites, shawls and curtains. The walls are vertical with many thin ribbons and curtains. A massive compound canopy together with gours and other speleothem deposits occurs at the northern end. Flowstones related to this group overlie, and therefore postdate, the red-brown earth floor. There are several subsidence pits. Horizontal cemented bands within the sediment have been left protruding from the bedrock walls next to these pits (Plate 5b). The solutions producing the speleothems entered the chamber through a master joint along its length together with several cross joints.

At the southern end of the main chamber (260008) there is a broad and rising flowstone floor which extends into the *Squeezes Section*. There are also large flowstone canopies and columns here, and the roof is richly decorated with stalactites. Further in, where the flowstone floor flattens, there are some dry gours up to 10 cm deep.

The flowstone forms a false floor and there is a second low crawlway below it (section 13, Map 7). The roof of this low section is the underside of the flowstone, with red earth breccia, limestone fragments and bones adhering to it, and some small younger stalactites. The walls are of cemented red-earth breccia alternating with old flowstone beds. The floor is of loose red-earth and gravel.

At 262005 there is a pit in the main chamber floor which also extends under the flowstone floor. The features seen here are similar to the low-level crawlway, but in addition there is a deposit of nodules of soft dark brown earth cemented in a light brown cement and beneath the cemented breccia there is a second, younger, flowstone floor which incorporates collapsed fragments of older flowstones and stalactites. There is some cave coral on the eastern, limestone, wall of this pit.

Further into the Squeezes Section, the first squeeze is through a flowstone constriction of the narrow walled passage. The second squeeze is between the low roof and a flowstone false floor. Beyond this is the Bone Chamber (238996); a low chamber about 5 m across with a very low, inaccessible continuation to the north. The roof is flat with shallow hollows up to 60 cm across. The loose red earth floor contained bone material and has been excavated by the Queensland Museum. The flowstone false floor of the second squeeze overlies cemented red earth with soft nodules and some bones. These deposits and their fossil faunas have been described and illustrated by Archer (1978).

The third, and final, squeeze is in loose earth below a low ceiling and ends in a small chamber beneath the rear entrance passage. It was in this area (about 241991) that a partial skull of *Protemnodon roechus* was found by D. Gillieson lying loose on the surface. This specimen is held in the Queensland Museum collection, F6132.

The rear entrance (VR-14E) is a near-vertical shaft which opens into the roof of an inclined passage that in turn opens into the small chamber at the squeeze. There is a flowstone canopy beneath the entrance shaft.

Beyond the rear entrance a low wide passage leads to the *Shawl Section* (240980). The roof of this passage is flat, with a few small blind avens, and is at the same level as the main chamber; the floor level here is higher than in the main chamber, and could therefore have a considerable thickness of sediment. That at the surface is a soft, dry, dusty dark-brown silt. Margot's Shawl was a prized feature of this section until it was broken early in 1974. The shawl occurred together with a large cluster of stalactites in a broad bell-hole at 240977. Some gours on the floor behind the shawl contain small crystalline calcite 'flowers.'

The low chamber beyond the shawl has lines of squat, and sometimes knobbly, stalactites hanging from joints along the roof. These are milky white and very coarsely cyrstalline; some have crystalline continuity throughout much of their body. There is a flowstone false floor at the far end of this chamber, about 30 cm above the present earth floor.

From the eastern end of the Main Chamber (271018) a gently descending passage leads down to the lower level of the cave: the *Foul Air Section*. The passage becomes smaller as it descends. Marks on the walls indicate that the sediment floor has been eroded by up to two metres in its upper part, but not at all at the lower end.

The Foul Air Section consists of a series of low passages with a few larger, and higher-roofed chambers, the largest (at 290038) is about 10 m long and 4 m at its highest point (section 7). The ceilings are flat or domed, and there are a number of bell-holes (Plate 6a). The walls and ceilings have a much more regular surface than the upper levels; the numerous small hollows and cavities are not present and instead there are broad curves. Joints tend to form lines of conical pits rather than the V-sections seen elsewhere. In detail the surfaces are powdery and smooth to finely fretted or granular in texture. Rounded pits (1 cm across and 0·5 cm deep) occur in places. Fossils are etched out in relief. Well-developed solution undercuts are seen on the walls at several levels (see sections) and indicate old water levels. The flat roofs also indicate old water levels at a time when the section was completely filled with water. Blades of limestone project from the walls and roof in the largest chamber (Plate 6b) but are not common elsewhere. The sloping fissure of section 8 is due to solutional enlargement of an inclined joint.

Speleothems are not common; the most abundant deposits being in the large blind shaft in the furthest chamber (275041). This has many stalactites and a large column with a nodular, somewhat eroded, surface which has been fractured and the lower part subsided about 20 cm. The broken surface has been covered by younger speleothems. A low passage to the west of this area has a flowstone floor with a few gours. Some conical stalactites in this area have small helictites up to 1·5 cm long extending from their sides.

Radiating bunches of calcite crystals are seen growing from joints in two places in the Foul Air Section (294025 and 305030). A broad flowstone false floor occurs at 287031 (section 7) about 10-20 cm above the present floor level. In a small chamber at 305031 the walls originally had a brown speleothem coating about 1 mm thick which has now largely flaked off.

The floor of the Foul Air Section is generally flat and composed of a dark brown to reddish earth. There are several small subsidence pits and a low mound in the large chamber. The sediments are at least 4·5 m deep in auger hole RA-2. Shannon (pers. comm.) reports that when the cave was first discovered fresh looking current markings could be seen on the floor. These indicated flow from the short branch at 294014 northeastwards to 315038. Earth mounds at the ends of these two chambers were suggestive of current formed deposits. Further observations on flow markings left by the February 1976 flooding are given in Shannon (1976a).

THE SEDIMENTS OF RUSSENDEN CAVE: Augering has shown that there is more than 5 metres of sediment in the Main Chamber of the upper level, and more than 4·5 m in the lower Foul Air Section.

The red earth breccias of the Squeezes Section have been described by Archer (1968), who assigns a Pleistocene age to their fauna. Their relationship to the earth and clayey deposits of the main chamber is not certain but they are thought to be older; the flowstone of the false-floor, which overlies and cements the breccia, may be contemporaneous with the columns at 250024 which extend at least 50 cm below the surface sediments and therefore are either older than or contemporaneous with the earthy sediments.

The main body of younger sediments are composed of clays and silts with a coarser admixture made up of clay aggregates together with small nodules and fragments of cemented material. There are many similarities with the sediments of Main Viator Cave, but also some significant differences: (a) clay aggregates, though present, are much less widespread; (b) with the exception of the active guano pile at 271017 (which has no correlate in Main Cave), the deposits are neutral to mildly alkaline (pH ranges between 7 and 7·75), and pH does not vary with depth; (c) the sediments are nearly all phosphatic, sometimes strongly so; (d) those of the upper level are generally calcareous, particularly in the upper parts where bands of calcareous cement are common. Detailed descriptions of the auger samples, together with sections in the subsidence pits and the old guano pile are given in Grimes (1977). The distribution in the Main Chamber is illustrated in Fig. 3 and the main features are summarised below.

The main surface deposit, unit A (Fig. 3), of the upper level of the cave was sampled in RA-1 and RA-4 and also examined in the natural pits in both the Main Chamber and the Red Earth Section. The unit consists of up to 2·8 m of reddish-brown earth (10R 4/4–5/4) with thin hard cemented bands and granule-sized nodules of cemented, honeycombed earth. Median grain size varies from the fine sand to medium silt range. In the main chamber pit there were patches of very dark brown to black, hard, sand-sized particles which might be manganese oxides. A few small bones and a fragment of a speleothem were also present in this pit. The unit extends into the Red Earth Section where it contains some bands of cemented white nodules. In RA-1 unit A includes a thin bed between 0·8 and 1·3 m depth which is a very soft, 'fluffy', greyish yellow-brown (10YR 5/2) sandy earth with a few thin cemented bands. It is phosphatic and calcareous. It could represent a thin bed of guano material.

Below the red-brown earth unit in the Main Chamber is a second unit, unit B, which was penetrated by RA-1 (below 2·8 m) and RA-4 (below 1·4 m) and which is also exposed in lowest part of the pit between the two holes. This is a dull to bright reddish-brown (2·5 YR 5/4–5YR 2/4) and greyish yellow-brown (10YR 5/2) compact clay and silt, with a few lighter coloured clay aggregates. There is a darker brown (5YR 2/4) bed between 3·75 and 4·2 m in RA-4. In the pit the unit contains pebbles and cobbles of limestone and speleothem material and some bone fragments. It is calcareous and moderately phosphatic.

At the bottom of RA-1 (4·3–4·43 m) a black and white (salt-and-pepper pattern) gritty clay overlies hard rock. This is similar to unit 5 of Main Viator Cave, which overlies speleothem material. It is not possible to tell the nature of the underlying rock in this case as no chips were recovered.

The talus cone, unit C, below the main entrance is a typical entrance facies containing a mixture of dark brown surface soil and rock fragments up to 1 m across. The maximum slope angle is 30°. On the northern side of the cone probing with a metal rod indicated the presence of rocks beneath the floor deposits. The entrance facies must therefore be older than or contemporaneous with the upper sediments of the Main Chamber (see Fig. 3). The talus cone also overlies a cemented floor level in the vicinity of RA-3.

Auger hole RA-3 was spudded in about half a metre below the level of the cemented floor under the talus cone and penetrated Unit D. This shallow hole first went through 0·75 m of pale yellow-grey (10YR 7/2) powdery and gritty earth with chips of light grey clay and cemented material. This section is strongly phosphatic and may include some guano material, though its pH (7·5) is higher than the main old guano pile. Beneath this is a reddish-brown (5YR 5/7–4/6–5/4) and pale yellow-brown (10YR 6/2) earth with some white specks and hard chips. The hole bottomed on a hard rock at 1·45 m depth; in view of its position this rock is probably part of a buried rockpile or talus cone. The sequence in this part of the cave would therefore be (from bottom up): older entrance facies (talus); pale earth and guano; flowstone cemented floor; younger entrance facies (present talus) (Fig. 3).

Unit E, the old guano pile at 271017, also has a cemented surface. This pile contains a number of unusual minerals which were identified by P. J. Bridge. A measured section here consisted of (from the top): 10 cm of hard nodular cemented material containing gypsum and ardealite; 10 cm of soft white powdery gypsum; about 60 cm of dark brown (7·5YR 3/3–4/4) earth with some almost black bands. This unit contains whitlockite, taranakite, and apatite in guano dust. Below this was a basal unit more than 75 cm thick which extends into the nearby subsidence pit. This was composed of hard white material containing taranakite, with minor leucophosphite, quartz, and apatite. A more detailed section is given in Grimes (1977). The pH values range from 6·5 to 3·0 and the sequence gave phosphatic reactions throughout.

In the Foul Air Section RA-2 initially penetrated 0·5 m of phosphatic greyish-brown to dull orange (5YR 6/2–6/4) friable earth with white flecks and cemented bands.5%8s mah o equivalent to unit A. A 10 cm cavity below a cemented band was followed at 0·6 m depth by Unit F: red earth and clay (10R 4/6) with beds of dull yellow-orange clay (10YR 7/4–7/3). The

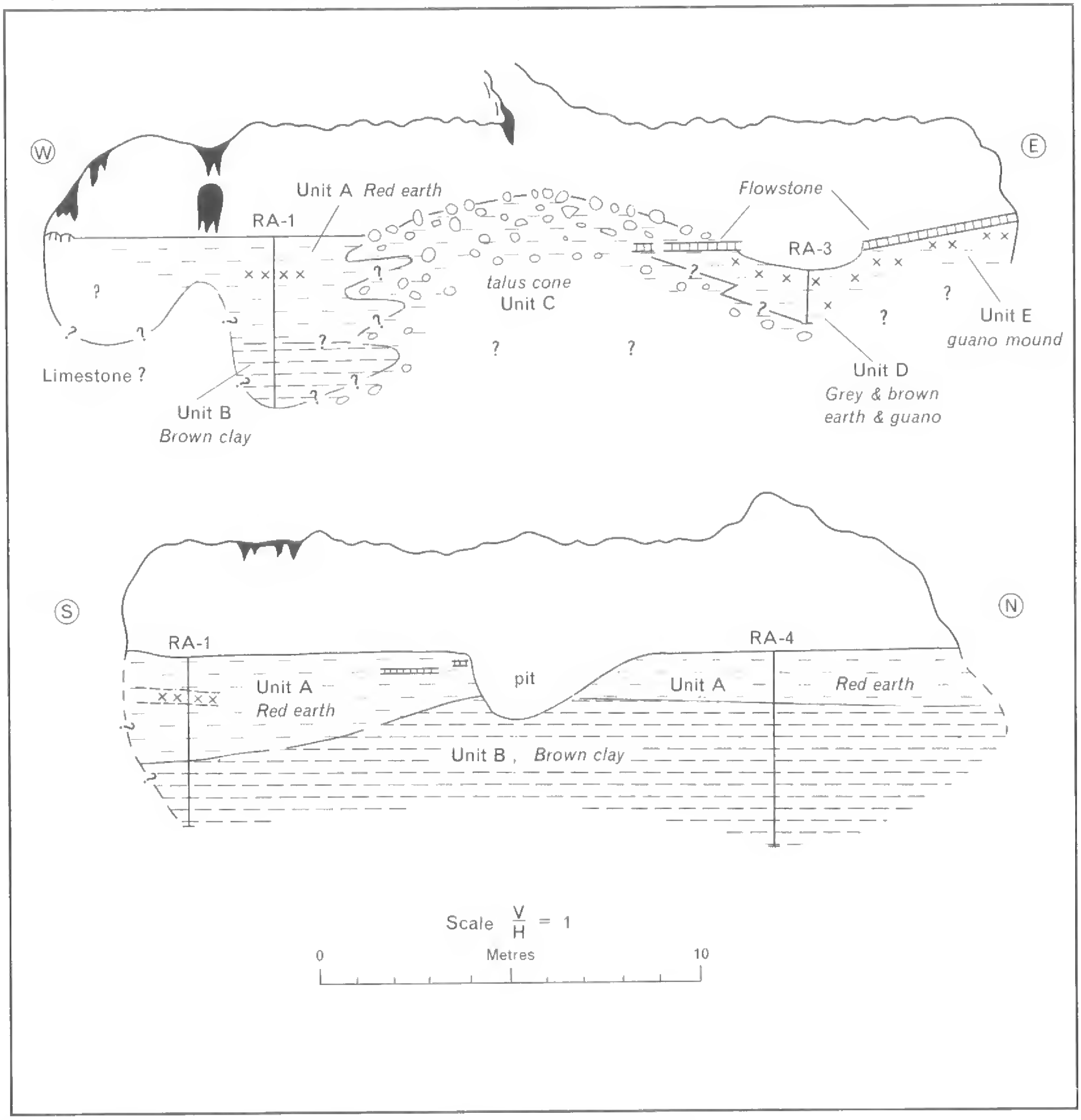

FIG. 3: Distribution of sediment in the Main Chamber of Russenden Cave.

latter became dominant below 2·3 m and contained granule and pebble-sized aggregates of red, light brown, and orange clay. This material continued to the bottom of the hole at 4·5 m. Unit F was only weakly phosphatic and poorly calcareous. X-ray analysis of clay minerals from this hole showed the presence of both Illite and Kaolinite; the former being dominant in the upper levels and the latter at depth (Grimes 1977).

THE SMALLER CAVES OF VIATOR HILL

There are fifteen small named caves on Viator Hill and a number of small unnamed potholes (see Map 10). The small caves exhibit a variety of forms which are divided into four main groups in this discussion, though there are some transitional types. These groups are: (a) The simple pots; (b) simple joint controlled fissure caves; (c) a dominantly horizontal system; and (d) pot or fissure entrances with horizontal extensions from the base. The last group is the most complex.

THE SIMPLE POTS

Simple pots are more or less vertical, cylindrical to elliptical shafts with minimal enlargement at the base (e.g. VR-17, Map 5). The simplest (unnamed) forms consist purely of a shaft which terminates in a rubble or earth floor. The most complex forms are transitional with group d.

TUMBLEWEED POT (VR-7): This cave has a tight inclined entrance passage which leads to a vertical, somewhat elliptical fissure about 5 m deep. The fissure widens towards the base to form a small chamber with a sloping floor of loose earth and rubble. There is some cave coral on the walls. Information is from UQSS members. No map has been compiled at the time of writing.

CRUISCIN POT (VR-8): There is a small entrance leading down to a single vertical chamber 8 m deep and 5 m long at the base. The walls have many hollows and pockets of phreatic form, together with some good examples of limestone blades and small windows in the walls. There is a rubble floor below the entrance. The walls have been undercut close to the floor level by a solution level which shows a gentle dip to the south. Beneath this undercut the floor is of flowstone and there are some stalactites. The chamber walls have cave coral and flowstone cover in places. A map of the cave has been published by the UQSS (see Appendix 1).

IRONWOOD POT (VR-9): This cave consists basically of two, one metre diameter, shafts, 5·5 m deep and separated by a solid rock partition with several large windows which connect the shafts. The shafts are smooth curved cylinders and could probably be considered to be rainwater inflow features superimposed on a phreatic origin. Information supplied by UQSS (see Appendix 1).

SADDLE POT (VR-17; see Map 5): There is a short inclined shaft which connects via a narrow slit to a small vertical fissure with an earth and rubble floor. The total depth is 7 metres. The walls of the fissure are sculptured by vertical runnels. At its base there are several low rounded cavities in the walls. These, together with the presence of some blades and windows between the cavities suggest a phreatic origin for the lower part of the cave. The upper parts can be classed as rainwater inflow shafts.

U-TUBE POT (VR-18): J. Toop (pers. comm.) describes this as about 5 m deep and consisting of an inclined shaft leading to a small chamber which connects to a second narrow vertical shaft from the surface. It has not been mapped at the time of writing.

SIDE-SADDLE POT (VR-21): A narrow, 4 m deep vertical shaft leads to a small, low rubble floored chamber. A nearby surface fissure has been excavated and leads to the same chamber. The main shaft has some deep sharp-edged scallops on the vertical walls (0·5–1·5 cm diameter) due to solution by inflowing rainwater. The cave has not been mapped at the time of writing.

FISSURE CAVES

Fissure caves develop as vertical or steeply inclined fissures reaching to the surface to form one or more entrances. They are solution enlarged joints.

THE JOINT (VR-5; see Map 4): This cave has a small entrance fissure which connects with a second long narrow fissure with an earth or rubble floor and a roof blocked at varying heights by red earth or by botryoidal white speleothems (see Archer 1978, pl. 10). The red earths are also plastered to the walls in places, they contain bone material which has been studied by Archer (1978).

Below the entrance the rock surface is fresh limestone with deep scallop-like pits and runnels (10–20 cm wide and 5–10 cm deep) due to inflowing rainwater. The walls of the two fissures have intersected several vertical, cylinderical shafts which now remain as truncated wall and floor cavities (see plan, Map 4). These shafts appear to be old rainwater inflow routes and may have provided the entrances through which the red earth and its bone material entered the cave. The upper parts of the shafts are now plugged by red earth and speleothems (see Archer 1978, pl. 10D). Their walls are covered by reddish flowstone deposits, as are parts of the main fissure. The connection between the two fissures is through a narrow key-hole window in the side of a small vertical cylindrical shaft. At the far end of the main fissure a horizontal flowstone forms a false floor about a metre above the present floor. Foul air is commonly present in this cave.

MIKES POT (VR-6): There is a 12 m deep entrance shaft which is elongated at first but becomes cylindrical at the base, with rainwater scallops and runnels on the walls. Part way down this shaft a window opens into a second shaft which is plugged above by reddish stalactites and flowstones. The base of this second shaft opens into an elongate fissure about 0·5 m wide and 17 m long and with a roof up to 4 m high. There are abundant roof decorations and some flowstones on the walls. The floor and roof of the fissure drop in several steps until finally it becomes completely filled by sediment at a depth of 19 m below the entrance. A map has been published by the UQSS (see Appendix 1).

MUDSLIDE POT (VR-15): This is a small cave consisting of an open fissure partly blocked above by rockpile. A second sloping fissure connects to the first at its base and is separated from it by a large hanging wedge of rock. The cave has been surveyed by UQSS but the map has not yet been plotted.

DEAD SHEEP HOLE (VR-16; see Map 5): This is a simple, small fissure cave, about 5 m deep and 9 m long with several daylight holes between large blocks which close off the top of the fissure. The floor is of brown earth and rubble. There are some small flowstones on the walls and the ceiling.

HORIZONTAL SYSTEMS

CRYSTAL CAVE (VR-3; Map 2): This cave is the only one of its type on Viator Hill. The cave has also been known as 'The Grotto' or 'Crystal Grotto' (Shannon 1968). A short inclined entrance leads down 3 metres to a small chamber. From the base of the chamber the cave continues as a wide, low-roofed passage, extremely well-decorated with numerous white, coarsely-crystalline, conical stalactites and columns which often obscure the walls and obstruct the passage in many places. Some flowstones also occur on the walls and floor. Elsewhere the floor is earthy with some rubble. Where not obscured by stalactites, the ceiling is smoothly undulating with a powdery weathering surface. A small chamber at the rear of the cave is 2 m high with a domed ceiling.

POT OR FISSURE ENTRANCES WITH HORIZONTAL DEVELOPMENTS AT THE BASE

These caves have either more-or-less cylindrical rainwater inflow shafts similar to the simple pots or fissure entrance sections. They are distinguished from the simple caves by having a significant amount of horizontal development at their base.

BEVANS POT (VR-4; see Map 3): This cave has a 7 m entrance shaft, partly of solutional origin and partly formed between subsided blocks. At its base this shaft connects with two sloping fissure passages which open into the main chamber. The chamber has a U-shaped plan due to the presence of a large central block with, in places, only a few decimetres of space between it and the ceiling (see plan and section 4; Map 3). The floor is of rubble near the entrance but further in it is of brown earth with a westerly slope. The walls have smoothly rounded pockets separated by bluntly pointed blades; the ceiling has similar features and a dominantly phreatic origin is suggested. The rock surfaces are powdery. There are deposits of red earth, with some bone material, in the walls at several places. Flat bedded 'older' red flowstones are associated with these red earths and a correlation with the red-earth breccias of the nearby Main Viator Cave is suspected. The cave is well decorated with stalactites, shawls, curtains and ribbons, stalagmites, and flowstones. Speleothems are particularly abundant in dome shaped bell-holes in the roof.

DROP-IN POT (VR-10): A tight entrance squeeze leads to the top of an elliptical fissure about 8·5 m deep and 4 m long. The walls of the fissure are covered by cave coral and some flowstone. From the fissure a small passage leads to a small chamber, about 4 m across, with a flat roof and solution undercuts. The walls have a smooth powdery surface. The floor is of rubble beneath the entrance and elsewhere is a loose red earth. A dry stream channel crosses the floor from the entrance to the far side of the chamber. Information is from UQSS members; a map has been published by the UQSS (see Appendix 1).

CUNDOWIE CAVE (VR-11): A small, excavated hole leads to a vertical fissure, about 10 m deep, with muddy rock walls. At the base of the fissure there is a heavy growth of cave coral. Holes in the floor and at the northern end of the fissure lead to a low chamber, about 10 m long, with a rubble, earth and flowstone floor and a horizontal ceiling partly covered by cave coral. A low, flat roofed, passage leads to the west, past a large subsided block with a flowstone coating. Several short, low, tight passages lead off from this passage and from the main chamber. The flat ceiling appears to be a solution plane marking an old water level. A map has been published by the UQSS but has some major errors of scale and direction (Appendix 1).

RABSCUTTLE HOLE (VR-20; Map 6): This is a 10 m deep cave with two levels of horizontal development. An entrance shaft with rainwater inflow runnels and small scallops leads to an elongated fissure which has a horizontal solution plane crossing its lower part (The middle level – Map 6). A small passage with phreatic forms extends from this level and has flowstone and earth floor. The walls and roof of the fissure have an abundance of flowstones, cave coral, and stalactites, which block the extremities and partly cover the floor.

A continuation of the entrance shaft down through the floor of this middle level leads down to the lower level. This has a small chamber with several small bell-avens. Low, flat-roofed passages lead off from this chamber and appear to have developed at an old water level. Shannon (1975) considers that features on the walls of these passages are current scallops. This, as well as the flat ceiling, leads him to conclude that the passages are stream passages.

In the main chamber of the lower level the walls have smoothly surfaced pockets and a small window allows a view of a similar pocket to the northwest. These are phreatic features and predate the draining of the cave to the level of the flat roofed passages. The floor is of a loose red-brown earth with some small bones on the surface. Some older red-earths with bone material also occur at the middle level. More detailed descriptions of the cave have been given by Shannon (1975) and Grimes (1975).

The February 1976 flooding of this cave opened up a new passage which extended from the chamber for about 5 m back beneath the middle level (Shannon 1976b). This is not shown on Map 6.

THE WHALE ROCK AREA
(250220; Map 10)

There is only one small true cave in this area: Sagging Gut Cave. Other cave-like forms are an overhanging cliff above Pike Creek which forms a water filled rock shelter, and Whale Rock itself, which is a small rock in the middle of the waterhole that has a horizontal tube of water level which goes in about 2 m and then rises vertically to a hole, 'the spout', in the top of the rock.

SAGGING GUT CAVE (BRK-1): This cave has been described by Bourke (1970). It has two horizontal levels close to the ground surface and a final tight vertical squeeze which may lead to a third level. There is some cave coral and floor is of rubble and mud. The wall features suggest a phreatic origin which must predate the downcutting of Pike Creek adjacent to the cave. The cave had only been partly mapped at the time of writing.

HISTORY OF CAVE DEVELOPMENT

A relative chronology can be established for many of the erosional and depositional features within each of the major caves, and in some cases correlation is possible between the individual caves, and between events in the caves and the erosional and depositional history of Pike Creek. An absolute chronology is more difficult to obtain; The faunas of the cave deposits give some time control (Archer 1978), and approximate ages can be obtained from comparisons of the stream terraces with dated terraces and K-cycles further south (see geological section). The deduced sequence of events is listed in Table 1.

The caves were all initiated by phreatic solution when the bed of Pike Creek, and hence the 'water table', was above its present level. In the case of the Glenlyon System a stage of underground stream development has followed as a result of capture of part of the flow of Pike Creek. On the other hand the caves of Viator Hill show no strong evidence for the existence of rapidly moving streams and these caves appear to have followed a variation of the non-fluvial development pattern outlined by Frank (1972). C. H. C. Shannon (pers. comm.) disagrees with this viewpoint and postulates a previous diversion of water from Pike Creek through Viator Hill as a necessary stage in the development of its caves.

DEVELOPMENT OF THE VIATOR HILL CAVES

The caves of Viator Hill all show evidence of having grown mainly under slow moving phreatic conditions, i.e. nothophreatic in the terminology of Jennings (1976). This is evidenced by the irregular form of their passages and chambers on the large scale, and on a smaller scale by the presence of many solution hollows, pockets, blades, and other features in the walls and ceilings (Plate 6b).

In the larger caves horizontal ceilings (Plate 5c) and undercuts in the walls (Plate 5a) are evidence of solution occurring below a succession of levels as the caves were drained. Flat ceilings have been quoted by many authors as evidence for old water levels (e.g. Jennings 1971; Frank 1972; and literature cited therein), often with connotations of fluctuating levels between the flat ceiling (or top of the wall undercut) and the maximum extent of the wall beneath it. In addition rapid stream flow is often assumed. This latter assumption is generally not justified in the case of the Viator Hill caves where there are no scallops to suggest

TABLE 1: DEVELOPMENT OF THE TEXAS CAVES

TENTATIVE AGES AND CLIMATES[1]			GLENLYON SYSTEM			PIKE CREEK[2]
HOLOCENE		dry?	Silt mounds in stream passage Collapse of upstream entrance Vadose scallops and nitches	Speleothems	Doline collapse sequence	(Qha gravels, modern stream cliffs,) (soil stripping near cliffs and dolines)
	1000 BP?		Siltation?			Qa$_1$ terraces (383–4 m)
		wet?	(Incision of terraces and) (stream passage sediments)			Erosion of Qa$_2$ terrace
	4000 BP?	dry?	(385–6 m terrace in camp doline,) (siltation within caves)			Aggradation, Qa$_2$ terrace (388–9 m)
-?-		wet?	Vadose incision of cave floor?			Incision of creek bed (380–?)
LATE PLEISTOCENE		dry?				Possible aggradation?
		wet?	(Partial capture of Pike Creek and) (enlargement of main stream passages)	Phreatic formation		Incision of creek bed (–?–)
	30 000 BP?	dry?				Aggradation, Qpa gravels (390–395 m)
						Stream at 400–410 m?
		wet?				Stream above 411 m

(1) Climates and ages of terraces are based on the K-cycle theory, and correlations with dated terraces elsewhere in Australia.
(2) Elevations of Pike Creek and its terraces refer to the area between the Glenlyon System and Viator Hill.

strong currents, nor are there long linear passages of the type found in most stream caves (c.f. the Glenlyon System). Further there are often no apparent entrances or exits for through flowing streams at the levels of these features. Instead the flat ceilings of the chambers are generally surrounded by walls on all sides, and some of the higher wall undercuts make a full circuit of the chambers above the level of connecting passages. Some chambers with these features have only a single entrance and therefore could not have contained a through flowing stream. The situation therefore appears to have been one of partly drained phreatic chambers with standing pools of slowly circulating water.

Since draining, the main history has been one of deposition and erosion of sediments and speleothems, with some solution continuing at depth (Table 1).

The Viator Hill caves have not all developed at the same time. The highest caves would probably have developed first and progressively lower caves would have formed as Pike Creek cut down beside the hill and lowered the water level. Thus The Joint (VR-5) near the top of the hill would have been the first cave to form, and also the first to be drained and opened to the surface. It is not surprising therefore that the bone deposits in The Joint contain the oldest fauna in the hill (Archer 1978).

TABLE 1: CONTINUED

RUSSENDEN CAVE	MAIN VIATOR CAVE	THE JOINT
Speleothems Subsidence pits, Entrance closed Red earth (unit A) Brown earth/clay (unit B) Red and brown clay (unit F) guano ↑ guano ↓ mound ↑ entrance cone ↓ eroded ↑ younger bone beds ↓	'Younger' speleothems Breakdown rubble Chocolate earth (unit 1) red earth cone unit 2 unit 4 Red and brown clay (unit 3)	Speleothems Minor sediments?
Younger sedimentation begins	Younger sedimentation begins	
Wall undercuts in Foul Air Section? (Erosion of speleothems and breccias, solutional enlargement of lower levels) cave stream?	Lower wall undercuts? (Erosion of 'older' speleothems and breccias, solutional enlargement of lower levels) cave stream?	(Erosion of bone breccias)
Speleothems (Red earth breccias and older bone beds)	'Older' speleothems (Red earth breccias and bone beds)	
Opening of entrances Draining of upper level	Opening of entrances Draining of upper level	?
390.8 m solutional level Phreatic formation of upper level	384 m solutional level Water at 385–7 m Phreatic formation of upper level	Speleothems
		(Deposition of bone breccia)
		(Draining, opening of entrances)
		Phreatic formation

For the smaller caves on the hill the history of development approximates to the model of Frank (1972): (1) Phreatic solution of the cavities and possibly deposition of some residual clays; (2) Drainage of the cavities as Pike Creek lowered its bed, with some breakdown and development of entrances; (3) Accumulation of entrance facies sediments, rubble and surface soils with bone material in some cases, and development of speleothems; (4) Blockage of some or all entrances leading to a cessation or reduction of sedimentation so that speleothem development becomes dominant. In some cases (e.g. The Joint, Bevans Pot, and Rabscuttle Hole) two stages of deposition of sediment can be recognised. The earlier stage consists of partly cemented red earths, with or without bone breccias, and has now been largely removed by erosion or subsidence into deeper cavities. The later stage is made up of unconsolidated red and red-brown earths. These two stages are seen in more detail in the larger caves.

The two large caves: Main Viator and Russenden have the most complete record of development. These also follow Frank's (1972) non-fluvial model, though with some important variations. The main level of development of Main Viator Cave is about 5 metres below that of Russenden Cave and it may therefore have been initiated slightly later. However the difference is probably not significant in view of the likely variations in the 'water table' across the hill. The sequences within the two caves are very similar and are assumed to be contemporaneous (see Table 1).

The main level in both caves developed chiefly from solution by slow moving phreatic waters below a water level which must have been higher than 387 m in Main Cave and 391 m in Russenden Cave. The bed of Pike Creek was presumably at comparable levels on the respective sides of the hill. There are remnant gravels (Qpa) on the surface at these elevations which are probably contemporaneous. Some residual clays might have accumulated in the bottoms of these phreatic chambers, but such deposits have not been recognised.

As Pike Creek lowered its channel and approached its present course, the water levels in the caves would have dropped. Flat ceilings and horizontal solution undercuts in the walls indicate still-stands as the caves were drained. The ceiling level of 390·8 m in the Main Chamber of the Russenden Cave (Plate 5c), and the wall undercut at 384 m in Main Viator Cave are two which could have formed at this time. The lower levels might have formed then or might be due to later floodings when water levels rose again.

The removal of hydrostatic support within the caves would have resulted in some collapse of the ceilings and this, coupled with surface denudation which truncated high level blind shafts and fissures, would have resulted in the opening of entrances. Rubble and soil material from the surface could then be washed in to form the red earth breccias. Speleothem deposits also formed and were interbedded with the red earth breccias and often cemented them. These are the 'older' coarse grained flowstones of Main Viator Cave. In Russenden Cave there is not such a marked difference in crystal form or colour between speleothems of different ages but 'older' speleothems can be identified in the squeezes area from their stratigraphic relationships. The erosion of surface soils suggests surface instability, possibly due to a change towards an arid or colder climate, although the coarsely crystalline nature of the flowstones suggests that these were constantly wet so conditions cannot have been too dry. Alternatively the flowstones could have indicated short returns to a humid climate within a dominantly arid period. Surface instability should also result in aggradation of the surface stream (Butler 1959) but no stream terraces occur which can be assigned to this time: possibly any that formed were obliterated by younger deposits.

The red earth breccias appear to have been mainly transported by mass movements and are generally close to present or previous entrances. Associated bone deposits in Russenden Cave have been studied by Archer (1978) who suggests a late Pleistocene age. Some bones also occur in the breccias of Main Cave but have not been studied in detail.

A line of shallow depressions extends southeast from the Main Cave entrance (Map 10) and could indicate the existence of a lower and more extensive level of earth filled passages extending from the cave. This may be related to the low level development of the Foul Air Section of Russenden Cave.

The low level development and the erosion of the breccias and speleothem deposits in the higher levels are thought to be contemporaneous and to be due to a return to a wetter and possibly warmer climate. This climatic change would have produced a number of effects (deduced from the K-cycle model of Butler 1959, and others). Stream incision may already have commenced with the return to stability and the 'water table' would have been lowered as a consequence. However the rate of groundwater circulation would now have been increased by the wetter climate, and these waters would have been more aggressive in view of the thicker vegetation cover. The overall result would be active phreatic solution below the lowered 'water table' and the formation of the low level sections of the caves. The deposits in the upper levels would have subsided or been washed into these lower levels.

Shannon (pers. comm.) goes one step further and postulates that this low level development was in the form of a stream diverting waters from Pike Creek beneath Viator Hill. The stream incision and concurrent cutting of the stream cliffs on the northwestern side of Viator Hill (220310 on Map 10) may well have intersected some caves. The rapidity with which the caves drained after the January 1976 flooding, together with the way in which the water level in the newly formed pit in Main Viator Cave has since risen in step with the rise in the Glenlyon Dam, suggests a fairly permeable connection at present. Thus some movement of water from Pike Creek doubtless occurred.

However no definite stream formed passages can be seen at present, and the circulation may have been of a more diffuse form. From time to time UQSS members have reported 'stream passages' in the small caves of Viator Hill. These references are generally based on the presence of flat ceilings or wall undercuts which, as discussed earlier, do not in themselves imply strongly flowing streams.

Any stream entrances and exits would now be buried beneath the alluvial terraces of Pike Creek and the only part of the lower levels which has not been filled by later sediments is the Foul Air Section of Russenden Cave. Here we see only the uppermost part of the level and this has an overall morphology which suggests dominantly phreatic and epiphreatic solution. There are solution levels related to old water tables but there is no evidence of strong stream flows. No stream deposits have been identified in any of the caves on Viator Hill.

The line of depressions southeast of Main Cave have a linear and vaguely meandering form and this could indicate a concentrated stream passage draining water away from Viator Hill and much of the eroded cave sediment may have been removed in this manner, but this need not be part of a through flow cave.

The next stage in the development of the area was the aggradation of the bed of Pike Creek to form the Qa_2 terrace deposits. The water tables would have risen in consequence and some of the solution undercuts in the lower parts of the caves may have formed at this time if they do not date from the earlier drop in the water table. The 382·4 and 381·4 m levels in Main Cave may date from this time as no red earth breccias or older speleothems are found below this level.

Deposition of the younger sediments in the caves may be contemporaneous with the Qa_1 and Qa_2 terraces of Pike Creek and both effects could be due to a further stage of surface instability related to reduced vegetation and a change towards an arid or cold climate. The Qa_2 terrace has been tentatively correlated with K_2 cycle terraces elsewhere which are of late Pleistocene and early Holocene ages (see geological section). The possibility of vegetation changes caused by aboriginal man cannot be discounted as an alternative source of instability.

Deposition in the caves appears to have continued until quite recent times, though there might be a disconformity releated to the break in surface deposition between the Qa_2 and Qa_1 terraces. The sedimentary units found in Russenden Cave are generally different from those in Main Cave and there are also variations within each cave. These result from differences in source materials and conditions in the two caves. The presence of clay aggregates, particularly in the Main Cave deposits, suggests that the main source was from surface soils and their preservation implies transportation and deposition by mass movement with only minor water transport.

In Main Viator Cave the oldest sediments of this series appear to be the red and brown clays of unit 3 (see cave descriptions, and Fig. 2). This unit might be a facies equivalent of unit 2 or may predate it. It is similar to the unit F in Russenden Cave.

Unit 2 is the main deposit in Main Cave. The numerous and varied clay aggregates within it suggest a source from a variety of surface soils, and possibly some re-working of the old red earth breccias. Lateral variations within the unit probably reflect variations in the source materials from different entrances. Introduction of organic material (e.g. guano and plant debris) locally may also have contributed to the variation, though the generally low phosphate contents suggest that guano was not abundant. The laminated clay (unit 4) indicates the presence of a small semi-permanent pool in that area and might be due to a slightly wetter but seasonally fluctuating climate at that time. Speleothems developed within unit 2 in several places during its deposition. These could indicate a reduction in sedimentation, either due to temporary entrance blockages or to brief wetter climates with greater surface stability.

The chocolate brown surface earths (unit 1) are the final stage in deposition in Main Cave and these may still be forming in some parts of the cave. In other parts of the cave the sediments have been buried by rockfalls from the ceiling. 'Younger' stalagmites and flowstones have built up over the sediment floor in a few places and are active at present.

In Russenden Cave the earth floors of the Shawl Section, the Main Chamber and Red Earth Section, and the Foul Air Section are all at different levels although each is more or less horizontal (see sections on Map 7). This suggests that deposition occurred independently in each section and that they were separated by barriers. The Squeezes would doubtless be the barrier between the Shawl Section and the Main Chamber but the barrier between the latter and the Foul Air Section is less obvious; there may have been a rock barrier at depth but the most likely feature is the old guano pile which was being built up at the same time as the sediments. This could have been quite an effective barrier if mass movement was the main process and there were only small intermittent streams.

The oldest deposits in Russenden Cave appear to be the red and brown clays (unit F) found at depth in the Foul Air Section. These are not as phosphatic as the rest of the Russenden sediments and could therefore predate the old guano mound. There may have been a time break between the formation of this unit and the remainder of the deposits related to the break in surface aggradation between formation of the Qa_2 and Qa_1 terraces. Unit F is similar to Unit 3 in Main Cave.

In the Main Chamber of Russenden Cave the earliest deposits are the brown earths and clays of unit B (see Fig. 3). This unit could interfinger with the rubble of the entrance cone and may also be contemporaneous with the earliest guano deposits as it is phosphatic. The red earth unit A overlies unit B and forms the surface deposit. This unit has thin interbedded flowstones and cemented bands and occasional guano beds. It is interbedded with the entrance rubble cone (unit C) and is a lateral equivalent of the guano deposits (units D and E).

When the floor of the Main Chamber had built up to the same level as the old guano mound the intermittent streams from the entrance would have been able to flow down the far side of the mound and erode the present channel which leads down to the Foul Air Section.

Deposition in Russenden Cave was terminated by the blockage of the entrances which may be a recent event. Since then the main developments have been continuing speleothem development, subsidence of the natural pits in the floors, and probably some further erosion of the guano mound.

Development of the Glenlyon System

The present Glenlyon System is a stream cave modified by collapse and by blockage of its influx area. However, many of the side passages of the system show features which are inherited from an earlier phreatic stage. The history of development deduced for the system is not as complex as is the case for the Viator Hill caves, mainly because the Glenlyon System lacks a complex sequence of sediments and speleothem deposits (see Table 1).

As with the Viator Hill caves the initial low energy phreatic stage must have occurred when the 'water table', and hence the bed of Pike Creek, was higher than at present, but it may have commenced a lttle later than in Russenden and Main Viator Caves as the main levels of the Glenlyon System are at lower elevations, i.e. below 385 m. The flat roofs in several passages in the upstream parts of the system attest to a water level standing between 384 and 385 m. Pike Creek must have adopted a course close to its present form by this time and subterranean capture of part, at least, of its flow may then have occurred. Since capture an epiphreatic stream has enlarged the main stream passages to their present linear form with more-or-less elliptical cross sections. As Pike Creek continued to incise its course down to, and possibly below, the 380 m level, these passages would have been drained and a vadose system would have been established with possible incision of the passage floors at the lowest stage.

Draining of the system, together with surface denudation, would have initiated collapse of the larger chambers. The present form of the resulting dolines suggests that some have suffered a longer period of surface weathering and soil development than others. A possible sequence of collapse is as follows: (1) The conical doline at 040295 (Map 9) and the shallow doline to its east were first to collapse and destroyed a hypothetical southeasterly extension of the system from either the Nettle Moat caves or from the Central Doline area; (2) Collapse of the Camp Doline appears to have been next in the sequence and abandonment of the Dustbath stream passage in favour of the Swallow Arch route may have been a result of this collapse, or could have been consequent on the later collapse of the Central Doline; (3) The Central Doline collapsed; (4) Terrace deposits formed in Camp Doline, and to a lesser extent in the Central Doline (see below); (5) The Crater Doline and the group of small dolines to its south appear to have collapsed fairly recently, this collapse being responsible for the blockage of the Flattener and diversion of the underground stream to the Sewer; (6) The most recent collapse was that of the upstream cliffs which blocked the entrance to the system. This continuing history of collapse probably prevented the cave system from ever capturing the full flow of Pike Creek, which was therefore capable of maintaining its surface channel.

The terraces in the Camp Doline are at a height of 385–6 m and may be contemporaneous with the Qa_2 terrace which has a level of 388–9 m on the far side of Pike Creek, the lower elevation within the doline could be due to the lesser supply of sediment. Alluvial deposits in the Central Doline show only a poorly-developed terrace form but may be contemporaneous. Deposition within the caves would also have occurred at this time.

Later incision of Pike Creek and erosion of the Qa_2 terrace would have been accompanied by erosion of the sediments in the stream passages of the cave system, though the deposits in the side passages may have remained relatively undisturbed. Further deposition, contemporaneous with the Qa_1 terrace, may have been responsible for the gravels below the present stream bed.

The recent collapse of the upstream entrance would have reduced the stream flow through the cave. The current scallops in the stream passages appear to predate this collapse and their excellent preservation, together with the preservation of subsoil karren forms on the rotated blocks of the cliff, suggest that only a short time has passed since the collapse of this section.

Since the collapse the main developments in the system have been the growth of speleothems and possibly the formation of the sediment mounds in the stream passages as a result of the reduced energy of the system. Major floods still fill the system but currents would be much slower than before.

CAVE DEVELOPMENT AND CLIMATIC CHANGE

The development of the caves has been in stages which can be related to the history of Pike Creek: erosional and depositional phases within the caves appear to correspond to periods of incision and aggradation of the creek bed. Both the cave and surface stages may be related to climatic fluctuations. These cycles are superimposed on the long term incision of the valley of Pike Creek as a result of post-Miocene uplift.

Debate concerning the relationship between climates on the one hand and stable and unstable surface conditions on the other has not yet been resolved. The ideas of Butler (1967) are followed here in proposing the relationship between climates, surface processes, and cave development. In humid climates the vegetation cover stabilises the valley slopes and surface erosion is mainly restricted to incision of the stream beds (Butler 1967). Stream incision would lower the water tables adjacent to the stream and drain any previously waterfilled cavities in that area. The higher rainfall will however mean a greater circulation of ground waters at the lowered level, and the thick vegetation cover will make these waters more corrosive as a result of the humic acids present. Solution will therefore be active at depth and will produce a series of low-level cavities. Any earlier, or contemporary, sediments in the upper levels will subside or be washed down into these lower levels. If there is sufficient connection with the surface streams the resulting throughflow may remove much of the material from the system.

With a change to aridity, or to a colder climate, or both, the vegetation cover is reduced and soil erosion occurs. The stream beds will be built up because of the greater sediment load and terraces will be formed (Butler 1959). In the caves near the streams, the water table will tend to rise but overall circulation will be reduced and the waters become less aggressive. Where entrances are present the eroded surface soils will be washed or subside into the caves and, if the arid phase continues for long enough, they will eventually fill most of the cavities and block the entrances. As the vegetation adapts to a new climate, surface stability will return. The stream will start to incise its channel again and the water table will be lowered accordingly. The reduced precipitation will inhibit cave development and consequently there will be little record of this period in the cave history.

A return to a higher rainfall will trigger further cave development at depth and destroy much of the earlier sediments.

This concept of climatic control and the relationships between surface and subsurface development is the basis of the interpretation presented in Table 1.

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APPENDIX 1: LIST OF CAVE AND SURFACE MAPS FOR THE TEXAS CAVES

Most cave and surface maps of the area are listed here. The only omissions are some early maps which have been superceded by more recent surveys. In addition to the maps listed here the 1:250 000 Goondiwindi geological sheet (Senior 1973) and the 1:100 000 Texas topographic sheet provide regional information.

ASF Map No.	Coverage	CRG grade	Scale	Views[1]	Authorship	Date	Publication[2]
BORDER RIVERS KARST REGION (Texas Caves area):							
4 BRK. UQS 125	Surface map: Glenlyon, Viator Hill, and part Whale Rock. Showing topography, vegetation, and cave entrances.	–	about 1:6 000	P	K. G. Grimes	1973	
4 BRK. GEN 3	Limestone Deposits, Limevale – Riverton area.	–	1:100 000	P	J. E. Siemon	1973	*Geol. Surv. Qd Rep.* **80**: fig 5
4 BRK. GEN 20	Limestone deposits, Reedy Creek – Texas Caves – Riverton and Cragie areas.	–	1:48 000	P	J. E. Siemon	1973	*Geol. Surv. Qd Rep.* **80** : fig 22
4 BRK. GEN 21	Geology and Geomorphology, Texas Caves area.	–	1:10 000	P	K. G. Grimes	1975	This paper : Map 10
4 BRK1. UQS –	Sagging Gut Cave (Whale Rock area)		Surveyed in part by J. Toop, UQSS, but not drawn up.				
GLENLYON AREA:							
4 GL UQS 124	Surface features, upstream part of the Glenlyon system.	6	1:120	P	C. H. C. Shannon	?	—
4 GL. UQS 38	Downstream part of the Glenlyon system. includes 4 GL-7, -8, -9.	5	1:120	PLX	A. L. Brown	1972	—
4 GL. UQS 109	as above, at reduced scale	5	1:240	PLX	A. L. Brown	1972	
4 GL. GEN 1	Surface and subsurface karst forms, Glenlyon system.	4–7	1:1 000	P	K. G. Grimes, *et al.*	1975	This paper: Map 9.
4 GL1. UQS 122	Glenlyon Stream Cave	5	1:240	P	C. H. C. Shannon *et al.*	1968–70	—
4 GL1. UQS 49	as above, at reduced scale	5	1:480	P	C. H. C. Shannon *et al.*	1968–70	—
4 GL1. UQS 123	as above, at reduced scale and lacking much detail	5	1:960	P	C. H. C. Shannon *et al.*	1972	*Down Under,* **11** : 132
4 GL1. GEN 2	Glenlyon Stream Cave	3–5	1:500	PLX	C. H. C. Shannon *et al.*	1968-75	This paper: Maps 8a, b
4 GL3. UQS 108	Swallow Arch	6	1:120	P	C. H. C. Shannon	?	This paper: Map 9
4 GL6. UQS 120	The Dustbath	5	1:120	PLX	A. L. Brown *et al.*	1972–75	This paper: Map 9
4 GL6. UQS 119	as above, at reduced scale	5	1:250	PLX	A. L. Brown *et al.*	1975	*Down Under,* **15** : 7
4 GL7. UQS 109	Cloister Cave	5	1:240	PX	A. L. Brown	1972	This paper: Map 9
4 GL8. UQS 121	Efflux Cave	6	1:120	P	C. H. C. Shannon	?	This paper: Map 9
4 GL8. UQS 109	Efflux Cave	5	1:240	PX	A. L. Brown	1972	This paper: Map 9
4 GL9. UQS 109	Cliff Pit	5	1:240	PLX	A. L. Brown	1972	This paper: Map 9
4 GL10. UQS –	Nettle Moat (north)	4	Surveyed by C. H. C. Shannon, UQSS, but not yet drawn up				
4 GL11. UQS –	Nettle Moat (south)	4	Surveyed by C. H. C. Shannon, UQSS, but not yet drawn up				
RIVERTON AREA:							
4 RN1. GEN 1	Riverton Cave	3?	1:600	P	P. D. Dwyer	1965	Helictite. **4** : 7
4 RN1. UQS 39	Riverton Cave	5	1:240	PX	D. S. Gillieson *et al.*	1973	*Down Under.* **12** : 56–7

ASF Map No.	Coverage	CRG grade	Scale	Views[1]	Authorship	Date	Publication[2]
VIATOR HILL AREA:							
4 VR. UQS 43	Surface traverse : Viator Hill; relates VR-1, VR-2, VR-5, VR-6, VR-7, VR-8, VR-10, VR-11, VR-12E, VR-13E, VR-19E.	7	1:480	P	A. Sprent	1968	—
4 VR. UQS 133	Surface map and cave outlines; Viator Hill.	3–7	1:1 000	P	K. G. Grimes, A. Sprent,	1976	—
4 VR1. UQS 48	Main Viator Cave	5	1:240	PLX	C. H. C. Shannon, A. R. K. Watt, *et al.*	1970	—
4 VR1. UQS 50	As above, at reduced scale	5	1:480	PLX	C. H. C. Shannon, A. R. K. Watt, *et al.*	1973	*Down Under.* **12** 9–10
4 VR1. GEN 1	Main Viator Cave	5	1:500	PLX	C. H. C. Shannon, *et al.*	1976	*This paper:* Map 1a, b
4 VR2. UQS 47	Russenden Cave	4	about 1:400	P	C. H. C. Shannon	1968	*Down Under.* **8**:15, **9**:17
4 VR2. UQS 57	Russenden Cave	4	about 1:400	PX	C. H. C. Shannon	1969	—
4 VR2. GEN 1	Russenden Cave	4	1:500	PLX	C. H. C. Shannon & K. G. Grimes	1968–75	This Paper: Map 7
4 VR3. UQS 60	Crystal Cave	5	1:120	PX	D. S. Gillieson	1970	*Down Under.* **10**: 62
4 VR3. GEN 1	Crystal Cave	5	1:150	PLX	D. S. Gillieson & K. G. Grimes	1970–75	This paper: Map 2
4 VR4. UQS 61	Bevans Pot	5	1:60	PL	A. W. Graham	1971	*Down Under.* **10**: 107–8
4 VR4. GEN 1	Bevans Pot	5	1:150	PX	A. W. Graham, & K. G. Grimes	1971–75	This paper: Map 3
4 VR5. UQS 52	The Joint	4	1:120	PL	M. J. Graham	1964	*Down Under.* **3**:5, **12**:8
4 VR5. GEN 1	The Joint	4	1:150	PLX	M. J. Graham, & K. G. Grimes	1964–75	This paper: Map 4
4 VR6. UQS 53	Mikes Pot	4	1:120	PL	M. J. Graham	1964	*Down Under.* 3:6 & **11**:133
4 VR7. UQS –	Tumbleweed Pot		Surveyed by K. Williamson, UQSS, but not yet drawn up				
4 VR8. UQS 46	Cruiscin Pot	5	1:60	PL	D. S. Gillieson, *et al.*	1973	*Down Under.* **12**:52
4 VR9. UQS 45	Ironwood Pot	5	1:60	PL	D. S. Gillieson, *et al.*	1973	*Down Under.* **12**:53
4 VR10. UQS 44	Drop-in Pot	5	1:60	PX	D. S. Gillieson, *et al.*	1973	*Down Under.* **12**:53–4
4 VR11. UQS 59	Cundowie Pot	5	1:120?	PX	D. S. Gillieson, *et al.*	1971	*Down Under.* **10**:61
4 VR15. –	Mudslide Pot		Surveyed by J. Toop, UQSS, but not yet drawn up.				
4 VR16. GEN 1	Dead Sheep Hole	3	1:150	PLX	K. G. Grimes	1975	This paper: Map 5
4 VR17. GEN 1	Saddle Pot	3	1:150	PL	K. G. Grimes	1975	This paper: Map 5
4 VR20. UQS 110	Rabscuttle Hole	2–3	1:100	PL	K. G. Grimes	1975	*Down Under.* **14**:53
4 VR20. GEN 1	as above, at reduced scale	2–3	1:150	PL	K. G. Grimes	1975	This paper: Map 6

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[1] Views; P=Plan, L=longitudinal profile, X=cross section.

[2] Unpublished maps are held in the UQSS map collection.

APPENDIX 2

REPORT ON COLLECTIONS OF CARBONIFEROUS CORALS FROM THE TEXAS CAVES AREA

P. J. G. Fleming
Geological Survey of Queensland

Coral specimens collected by K. Grimes, March 1975, assigned Geological Survey of Queensland Locality numbers L.1671, L.1672, L.1673, and L.1675, have been determined as follows (see Map 10 for localities): L.1671, *Aphrophyllum?* sp., Rugosa indet., *Syringopora* sp.; L.1672, *Aphrophyllum* sp. c.f. *A. hallense* Smith, *Neozaphrentis* sp., *Syringopora* sp.; L.1673, *Aulina?* sp.; *Neozaphrentis* sp., *Syringopora* sp.; L.1675, *Neozaphrentis australis* Pickett, *Merlewoodia?* sp. or *Symplectophyllum?* sp.

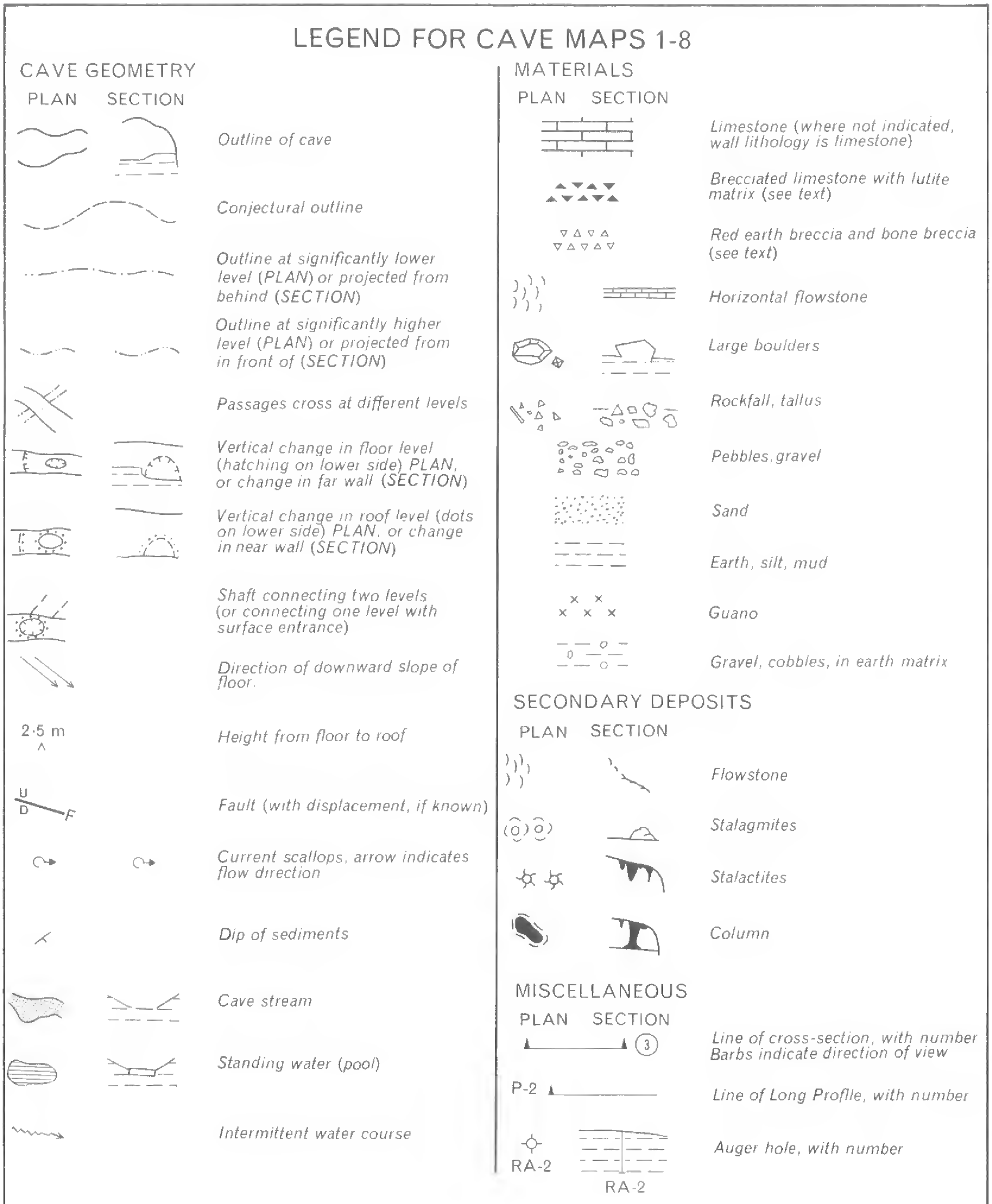
Discussion

Although some of the material on weathered surfaces appears to be well-preserved, recrystallization and other processes have rendered most of the corals unsuitable for detailed study. The generic compositions of the faunas from each of the localities indicates an early Carboniferous age, although only one species can be clearly identified. *N. australis* Pickett occurs in the early Carboniferous Rangari Limestone in New South Wales (Pickett 1966). *Aphrophyllum hallense* Smith is a cerioid colonial coral, but the specimens from L.1672, although apparently fasciculate, appear to be most closely comparable to *A. hallense* in their internal organization. *Aulina?* sp. from L.1673 is a small form with large lonsdaleoid dissepiments and short major and minor septa not reaching the axis. The small amount of material does not indicate identity with *A. simplex* Hill. *Neozaphrentis* forms are quite common in L.1672 and L.1673 collections. They normally have 22 major and 22 minor septa whose free lengths vary considerably, depending on the very variable width of the stereozone. The major septa reach only about half way to the axis, and the minor septa are almost covered by stereome in some specimens. A specimen from L.1675 is not determined, but resembles both *?Merlewoodia* sp. and *Symplectophyllum naoticum* of Pickett (1966; respectively pl. 10, fig. 6 and pl. 12, fig. 6). *Syringopora,* as in other early Carboniferous limestones, is usually present in small quanitities.

Taken as a whole, all of the corals present in these localities suggest a Visean age.

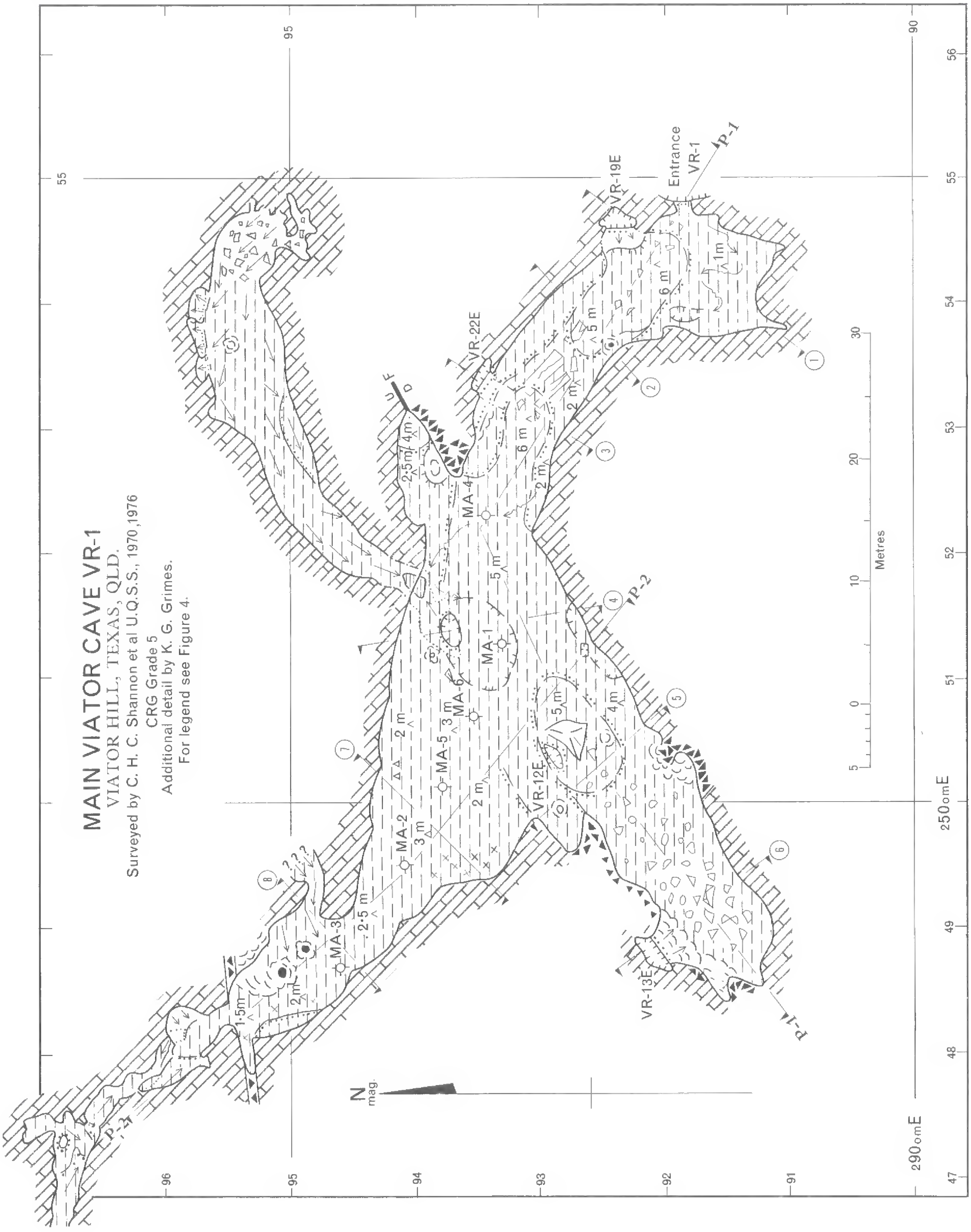
Literature Cited

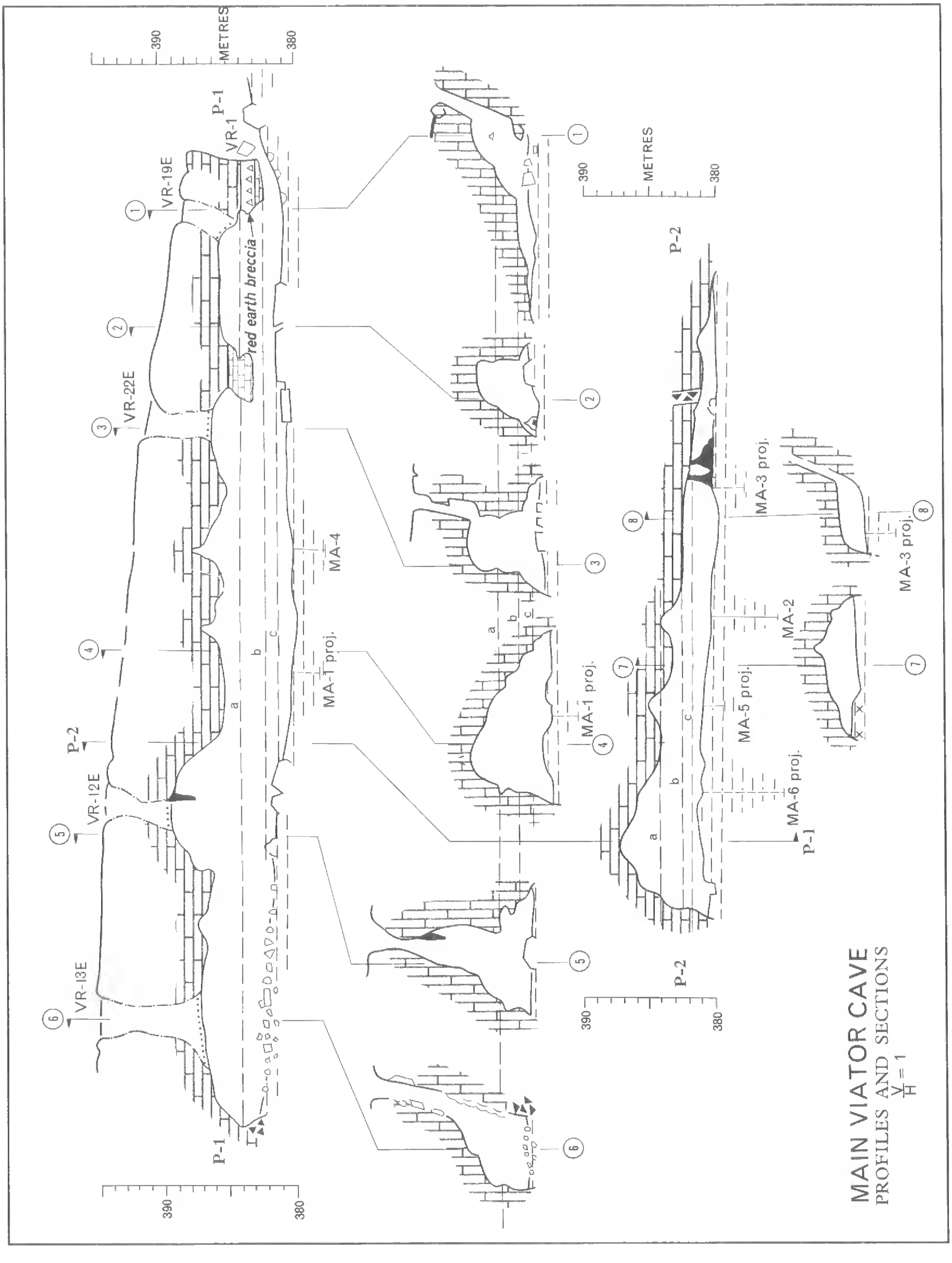
Pickett, J., 1966. Lower Carboniferous coral faunas from the New England district of New South Wales. *Mem. Geol. Surv. N.S.W., Palaeont.* **15:**


LEGEND FOR CAVE MAPS 1-8
CAVE GEOMETRY
PLAN
SECTION
Outline of cave
Conjectural outline
Outline at significantly lower level (PLAN) or projected from behind (SECTION)
Outline at significantly higher level (PLAN) or projected from in front of (SECTION)
Passages cross at different levels
Vertical change in floor level (hatching on lower side) PLAN, or change in far wall (SECTION)
Vertical change in roof level (dots on lower side) PLAN, or change in near wall (SECTION)
Shaft connecting two levels (or connecting one level with surface entrance)
Direction of downward slope of floor
2·5 m
Height from floor to roof
U
D
F
Fault (with displacement, if known)
Current scallops, arrow indicates flow direction
Dip of sediments
Cave stream
Standing water (pool)
Intermittent water course
MATERIALS
PLAN
SECTION
Limestone (where not indicated, wall lithology is limestone)
Brecciated limestone with lutite matrix (see text)
Red earth breccia and bone breccia (see text)
Horizontal flowstone
Large boulders
Rockfall, tallus
Pebbles, gravel
Sand
Earth, silt, mud
Guano
Gravel, cobbles, in earth matrix
SECONDARY DEPOSITS
PLAN
SECTION
Flowstone
Stalagmites
Stalactites
Column
MISCELLANEOUS
PLAN
SECTION
3
Line of cross-section, with number Barbs indicate direction of view
P-2
Line of Long Profile, with number
RA-2
RA-2
Auger hole, with number

The grid used in the cave and surface maps is orientated to magnetic north and has an origin 2000m West and 3000 m South of WC & IC Bench Mark 78A of Pike Creek Dam Capacity Plan. Elevations are derived from the same datum. Grid references for the cave maps use the last three significant figures and full co-ordinates are given in the South Western corner of each map. CRG grade numbers refer to the Cave Research Group of Great Britain system for grading Cave Survey standards, see Sexton (1968)

FIG. 4: Legend for cave maps 1–8.

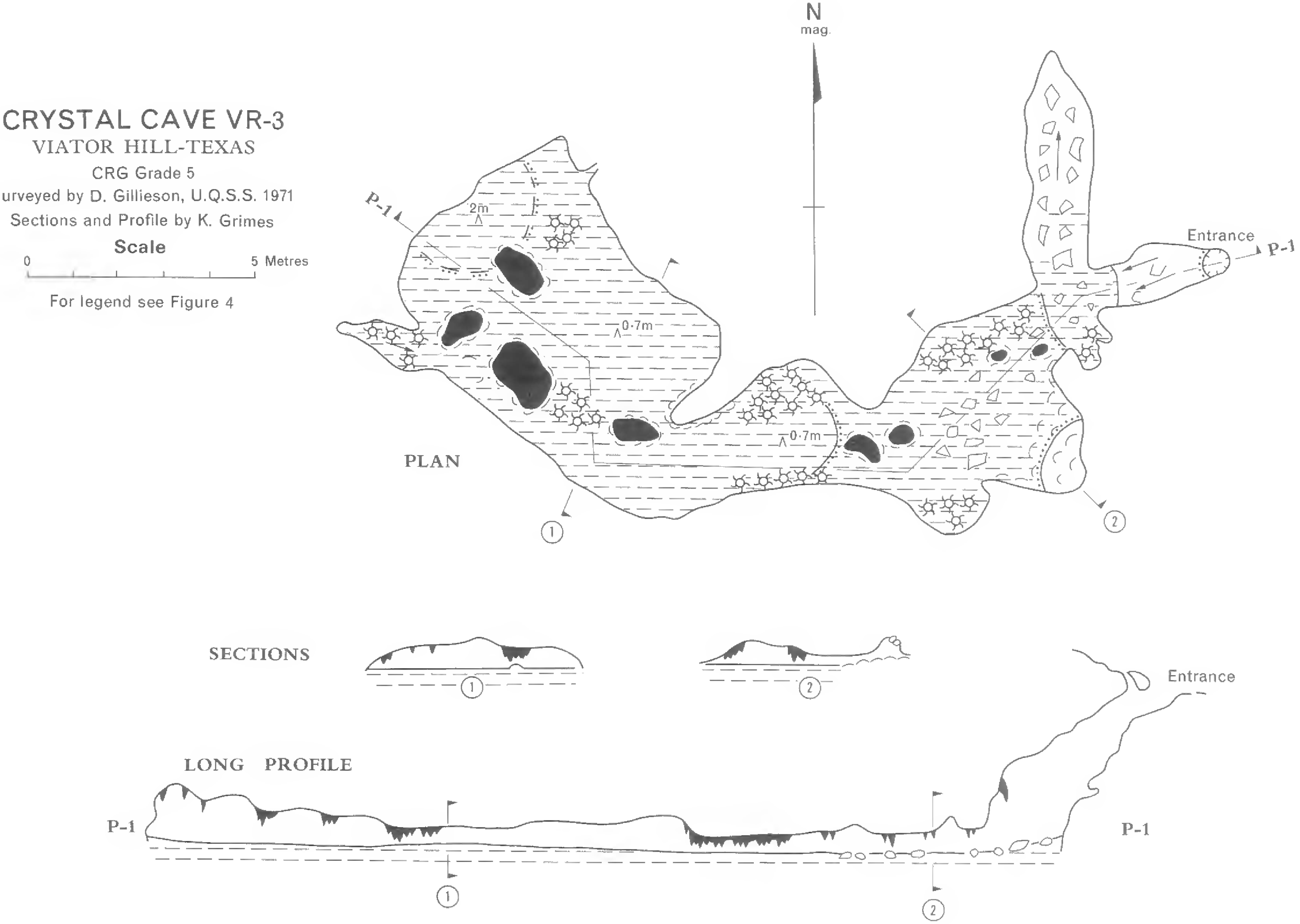

MAIN VIATOR CAVE VR-1
VIATOR HILL, TEXAS, QLD.
Surveyed by C. H. C. Shannon et al U.Q.S.S., 1970,1976
CRG Grade 5
Additional detail by K. G. Grimes.
For legend see Figure 4.
Entrance
VR-1
VR-19E
VR-22E
VR-12E
VR-13E
MA-1
MA-2
MA-3
MA-4
MA-5
MA-6
P-1
P-2
U
D
1
2
3
4
5
6
7
8
1m
5 m
6 m
2 m
4m
2·5m
3 m
2·5 m
1·5m
Metres
5
0
10
20
30
N
mag.
250omE
290omE
55
95
96
94
93
92
91
90
47
48
49
50
51
52
53
54
56

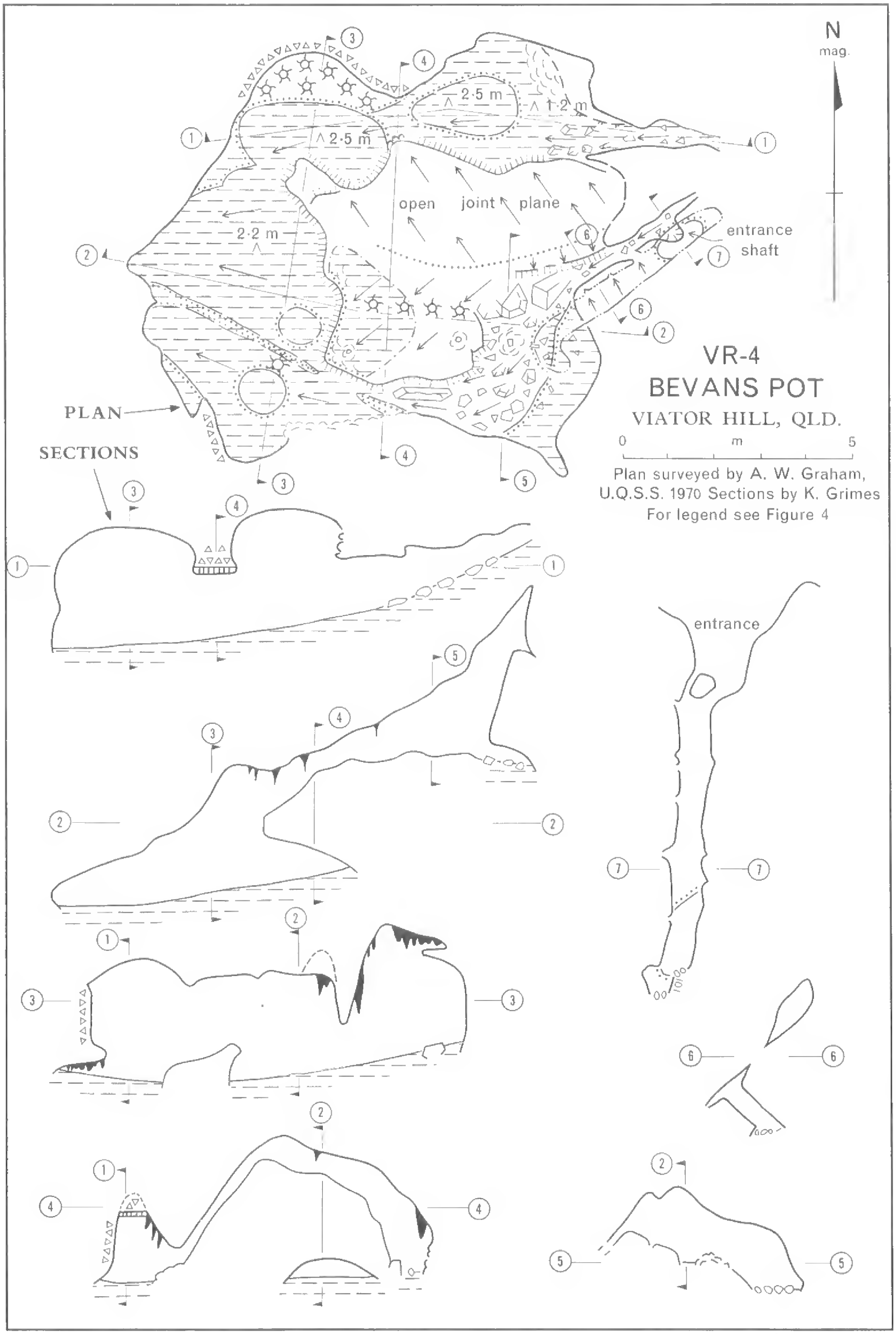


MAIN VIATOR CAVE
PROFILES AND SECTIONS
$\frac{V}{H} = 1$

CRYSTAL CAVE VR-3

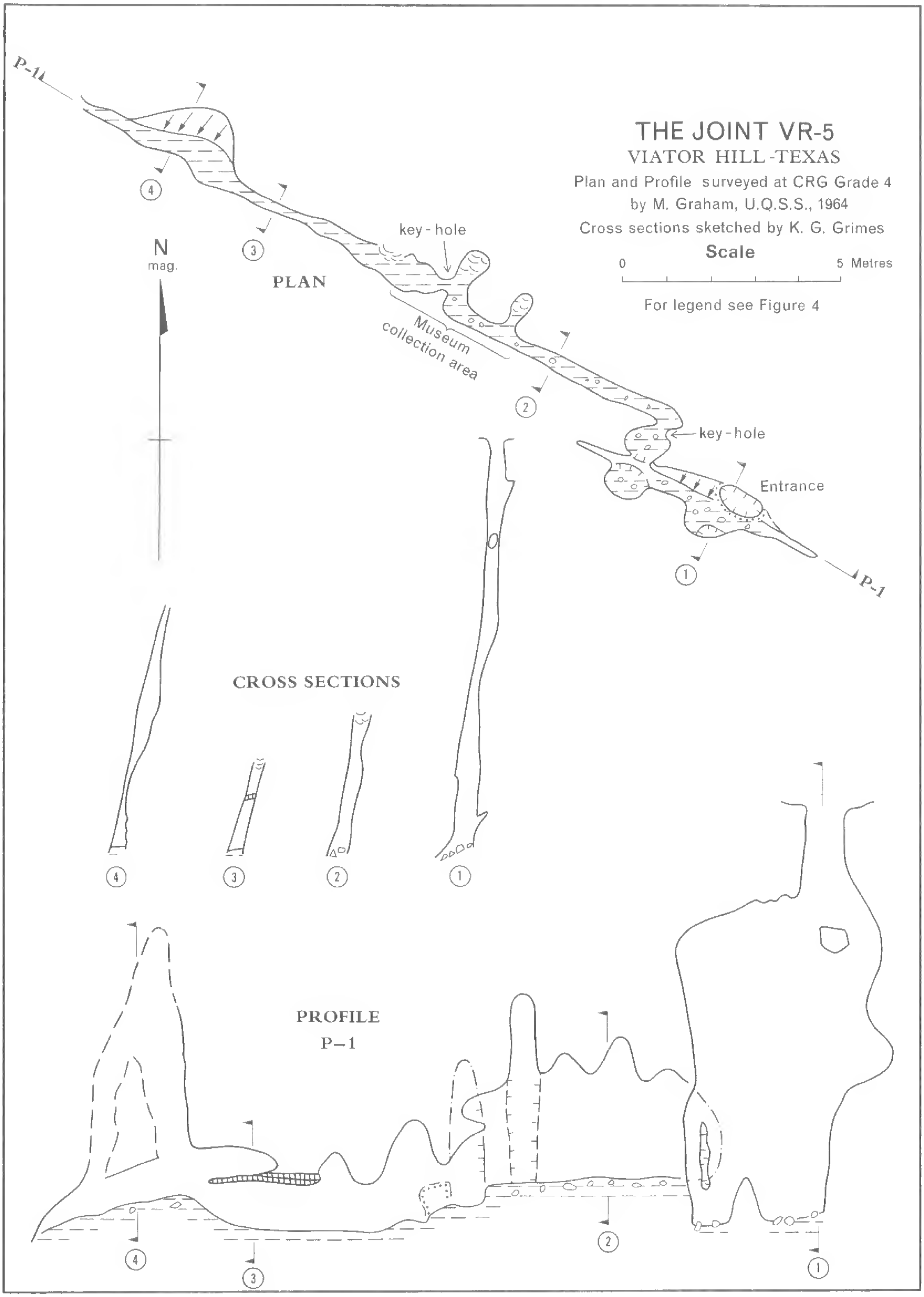
VIATOR HILL-TEXAS
CRG Grade 5
surveyed by D. Gillieson, U.Q.S.S. 1971
Sections and Profile by K. Grimes

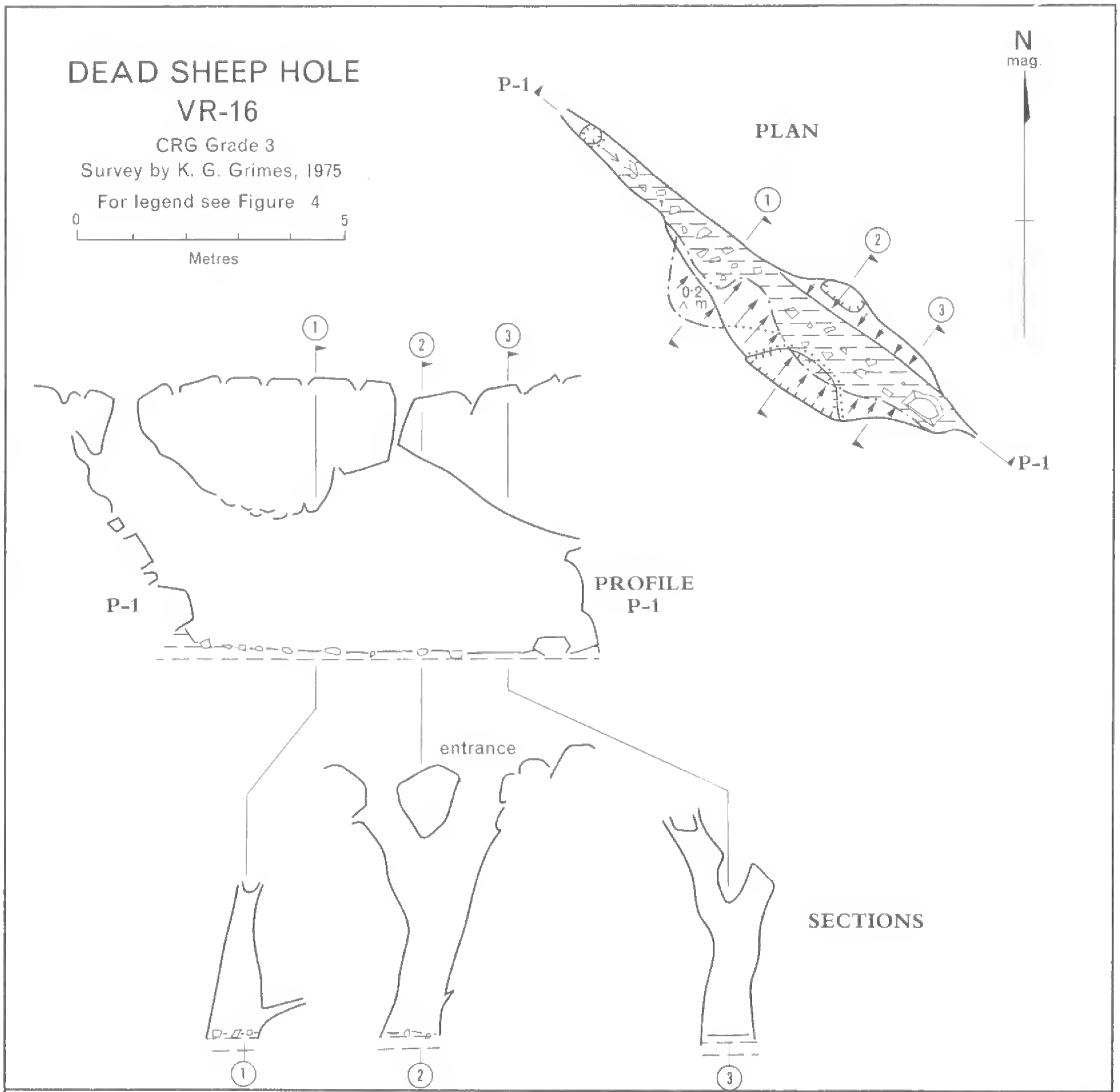


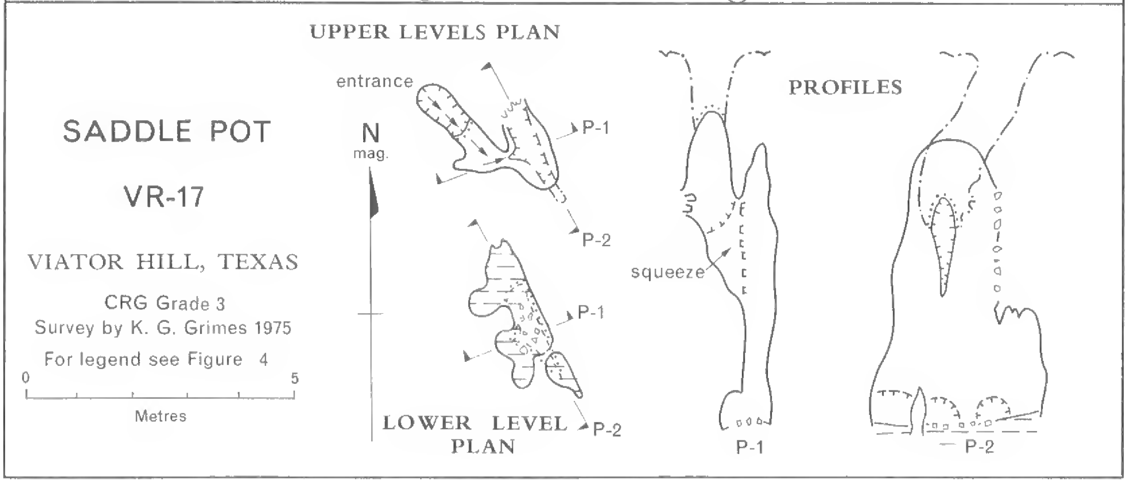


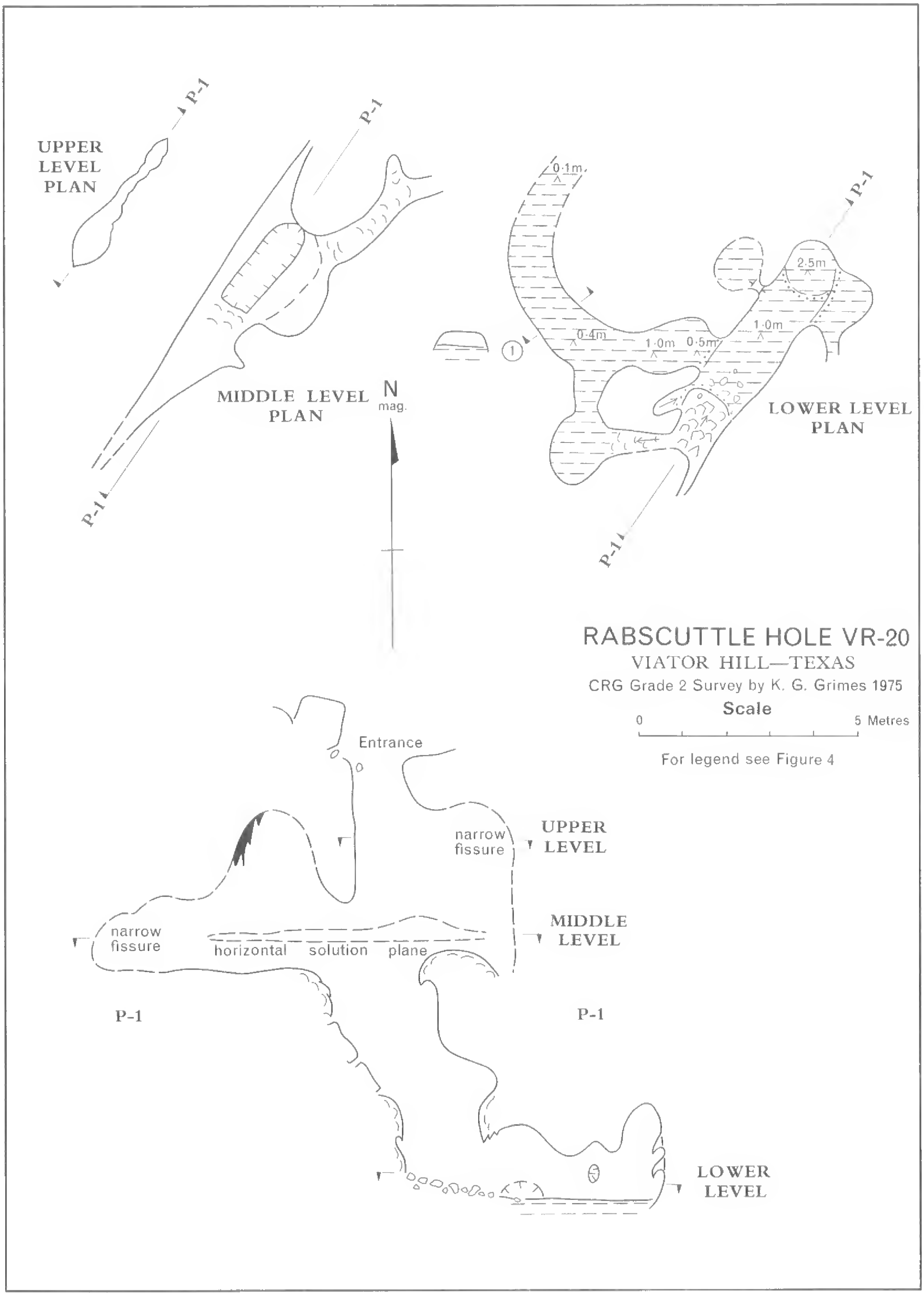
VR-4
BEVANS POT
VIATOR HILL, QLD.

Plan surveyed by A. W. Graham, U.Q.S.S. 1970 Sections by K. Grimes
For legend see Figure 4

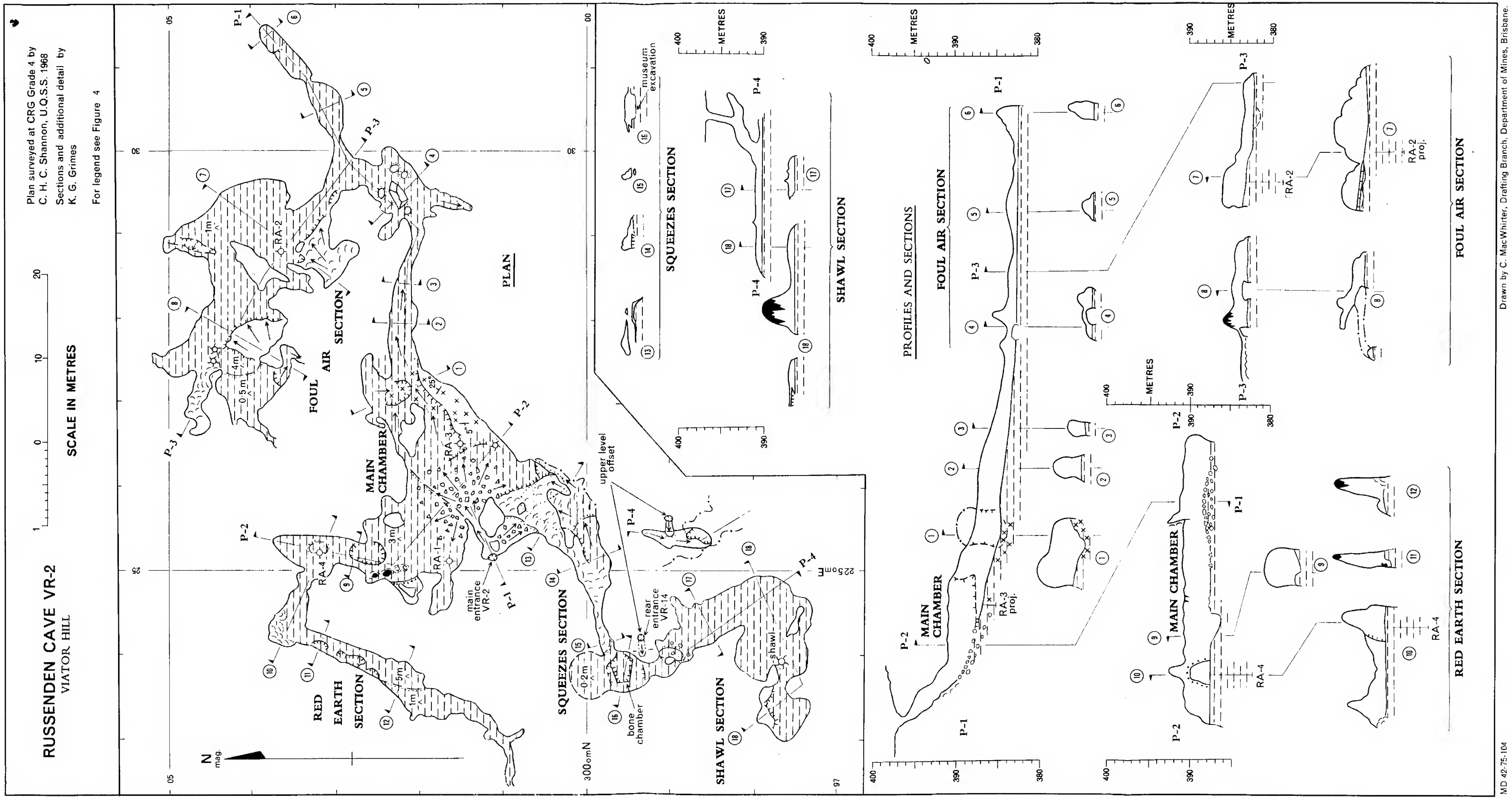

THE JOINT VR-5
VIATOR HILL-TEXAS
Plan and Profile surveyed at CRG Grade 4
by M. Graham, U.Q.S.S., 1964
Cross sections sketched by K. G. Grimes
Scale
0
5 Metres
For legend see Figure 4
N
mag.
PLAN
P-1
key-hole
Museum collection area
key-hole
Entrance
P-1
④
③
②
①
CROSS SECTIONS
④
③
②
①
PROFILE
P–1
④
③
②
①


DEAD SHEEP HOLE
VR-16
CRG Grade 3
Survey by K. G. Grimes, 1975
For legend see Figure 4
0
5
Metres
N
mag.
PLAN
P-1
P-1
1
2
3
0·2 m
PROFILE
P-1
P-1
entrance
SECTIONS
1
2
3


UPPER LEVELS PLAN
entrance
P-1
P-2
P-1
P-2
LOWER LEVEL PLAN
N
mag.
SADDLE POT
VR-17
VIATOR HILL, TEXAS
CRG Grade 3
Survey by K. G. Grimes 1975
For legend see Figure 4
0
5
Metres
PROFILES
squeeze
P-1
P-2



RABSCUTTLE HOLE VR-20
VIATOR HILL—TEXAS
CRG Grade 2 Survey by K. G. Grimes 1975



RUSSENDEN CAVE VR-2
VIATOR HILL

Plan surveyed at CRG Grade 4 by
C. H. C. Shannon, U.Q.S.S. 1968
Sections and additional detail by
K. G. Grimes

For legend see Figure 4